THE EFFECT OF LATERAL DISTRIBUTION OF LOAD OVER WIDE REINFORCED CONCRETE BEAMS

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This is to certify that the thesis prepared in the Department of Theoretical and Applied Mechanics by **EDWARD JOHN SCHELL** entitled The Effect of Lateral Distribution of Load Over Wide Reinforced Concrete Beams is approved by me as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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CONTENTS

Page

I Introduction 1

1 Purpose 1

2 Supervision 1

II Materials, Test Pieces and Method of Testing . . 2

3 Materials 2

4 Test Beams 5

5 Method of Making Beams 5

6 Storage 5

7 Method of Testing 5

III Experimental Data and Discussion 13

8 Summary of General Results of Tests. Table VI 14

9 Load Stress Diagrams 15

10 Manner of Failure 16

11 Ultimate Load 17

IV Conclusions 49

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I INTRODUCTION

1. Purpose.—The purpose of this thesis is to investigate the effect of concentrated loads upon wide beams. Tests were made in 1909 and 1910 at the University of Illinois by K. E. Robinson for the same purpose and reported in his thesis entitled "Tests of Reinforced Concrete Beams: Effect of Lateral Distribution". His tests were made on beams similar to those used in this thesis. Beams of different proportions between lengths, breadths, and thickness were tested with different widths of load applied at the one-third points of the span. The object was to determine the difference in effect between a load distributed over the entire width of a beam, and one concentrated in the middle portion of the beam. With this in view, the deformations of the steel reinforcing were measured across the center of the beam. Data were obtained in regard to the distribution of stresses, ultimate load, and manner of failure.

2. Supervision.—The Engineering Experiment Station of the University of Illinois is engaged in the investigation of the action of reinforced concrete in various forms. The tests described in this thesis were made under the direction of the Experiment Station staff and form a part of a more elaborate investigation of reinforced concrete beams. The interpretation of results and the conclusions drawn are original with the writer of this thesis and not

a part of the work of the Station.

II MATERIALS, TEST PIECES, AND METHODS OF TESTING

3. Materials.—The sand and stone were ordered under the same specifications as those given in the bulletins of the Engineering Experiment Station.

Stone.—The stone was a good quality of limestone from Kankakee, Illinois, ordered screened through a one inch screen, and was graded as shown in Table I.

Table I.

Mechanical Analysis of Stone

Sieve No.	Per cent retained	Per cent passing
1 in.	0.0	100.0
3/4 in.	4.7	95.3
1/2 in.	35.7	59.6
3/8 in.	24.5	35.1
3	17.1	18.0
5	14.1	3.9
10	1.1	2.8
Pan	2.8	0.0

Sand.—The sand used came from near the Wabash river at Attica, Indiana. It was relatively free from dirt and was graded as shown in Table II.

Table II.

Mechanical Analysis of Sand

Sieve No.	Per cent retained	Per cent passing
3	0.1	99.9
4	0.7	99.2
5	2.5	96.7
10	22.2	74.5
12	7.0	67.5
16	6.9	60.6
18	10.7	49.9
30	20.1	29.8
40	12.4	17.4
50	10.0	7.4
74	4.0	3.4
150	2.2	1.2
Pan	1.2	0.0

Cement.—Universal Portland cement was used with two exceptions, namely, beams number 749.1 and 749.2. Lehigh Portland cement was used for these two. The Universal Portland cement was graded as shown in Table III. The tests for tensile strength are shown in Table IV.

Table III.

Mechanical Analysis of Portland Cement

Sieve No.	Per cent retained	Per cent passing
100	3.5	96.5
200	17.5	82.5

Table IV.

Tensile Strength of Neat Universal Portland Cement

Number	7 days	28 days
1	585	660
2	580	670
3	590	675
4	615	675
5	575	680
	589	672

The tests for tensile strength of the Lehigh portland cement are shown in Table V.

Table V.

Tensile Strength of Neat Lehigh Portland Cement

Number	7 days	28 days
1	720	780
2	715	835
3	670	760
4	750	830
5	780	820
	727	805

Concrete.—A 1-2-4 mixture was used for all of the specimens with the exception of beam number 749.2 in which a 1-1-2 mixture was used on account of the necessity for shortening the time of setting. Men in the employ of the Experiment Station, who were accustomed to making the concrete, mixed the material and made the test beams. The mixing was done with shovels by hand.

Steel.—All the steel used was mild steel, and came from the Illinois Steel Company. The yield point was about 40 000 lb. per sq. in.

4. Test Beams.—The summary sheet page 14 gives dimensions of the test beams; the numbers are those which will be used in the subsequent discussion to designate the various specimens.

5. Method of Making Beams.—The beams were made directly on the concrete floor of the laboratory, a strip of building paper being laid beneath the beam to prevent its adhering to the floor. The forms were of the ordinary wooden knock-down type. Beams 749.1 and 749.2 were made with 6-in. 12 1/4 lb. I-beam supports imbedded in the concrete as shown in Fig. 2 page 9. The 24 1/4-in. square corrugated bars were bent down over the flanges of these I-beams.

6. Storage.—The beams were stored in a room the temperature of which was from 60° F. to 70° F. They were tested at the age of about 60 days, with the exception of beams number 749.1 and 749.2 which were tested at the age of about 30 days. The exact ages are given in the summary sheet page 14.

7. Method of Testing.—The beams were inverted and tested with the reinforced side up in order to facilitate measuring the deformations in the steel. The load was applied by means of a system of I-beams and rollers. Beam No. 742.3 was placed in the center

of the Riehle 600 000 lb. machine, and the load applied directly by the moving head. This, however, necessitated a very awkward and cramped position of the observer in the reading of deformations in the steel, which it was certain lessened the accuracy of the observations. Hence for the remainder of the tests in this machine (except those of beams 749.1 and 749.2) an apparatus somewhat similar to that shown in Fig. 1 for the 200 000 lb. Olsen machine was used which arrangement allowed the test beam to be placed in a position more convenient for the observer. The load on the beams tested in this way was, of course, only half that indicated by the weighing beam of the testing machine. Beams 742.1, 743.1, 743.3, 744.1, 744.3, and 746.1 were tested in this manner, and the photograph of beam 749.1, Fig. 4, shows th Riehle machine.The rest of the beams with the exception of beams number 749.1 and 749.2 were tested in the Olsen Beam Machine. The arrangement for the Olsen machine is shown in Fig. 1. A similar arrangement was used in the Riehle machine.

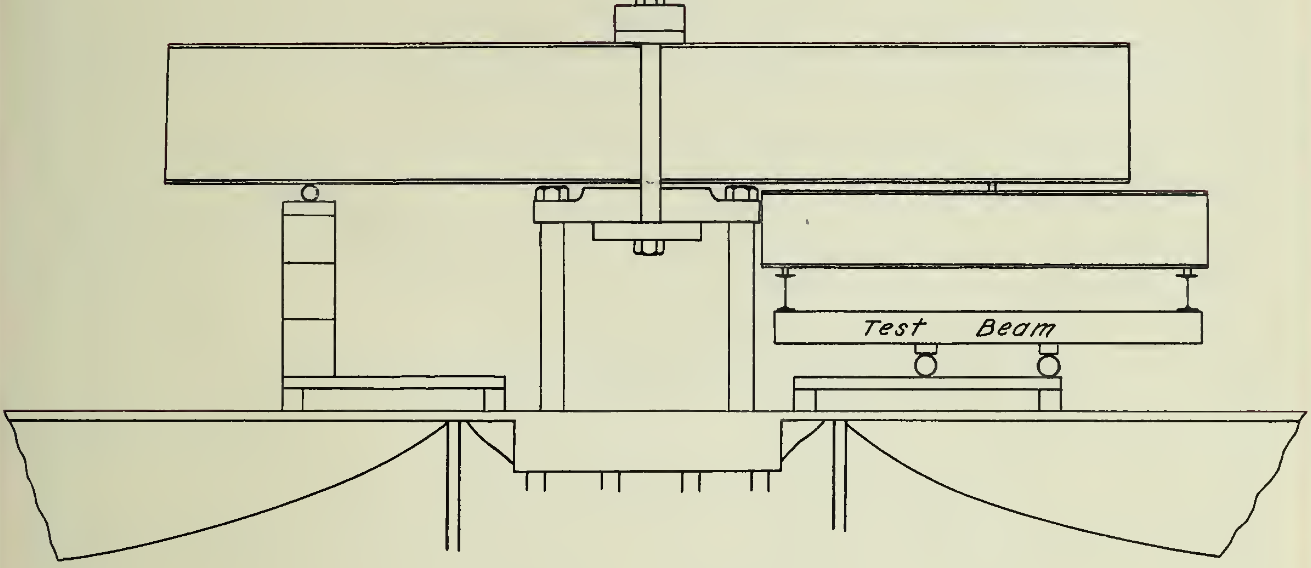
Beams 749.1 and 749.2 were tested directly in the Riehle Machine as shown in Fig. 2.

The load blocks were steel bars 3-in. wide by 1-in. thick cut off at different lengths for the different ratios of width of load to width of beam. They were imbedded in plaster of paris, except for beams 749.1 and 749.2 in which cushions of rubber hose were used, and supported upon rollers. The supports were I-beams imbedded in plaster of paris or in the concrete itself.

The deformations of the steel were measured by the Berry extensometer, the principles of which are shown in Fig. 3. The arm (a - b) is hinged at (b), and since the ratio of the distance a - b

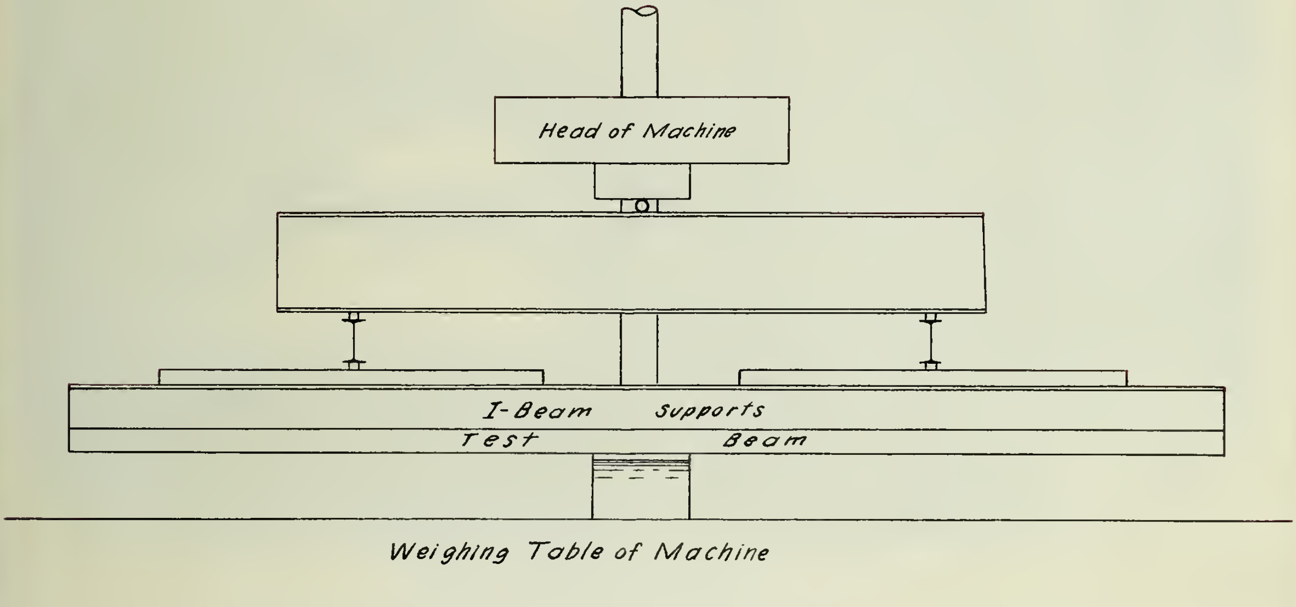
to the distance b – c is 5, a movement of .001 inches at (a) corresponds with an actual deformation in the steel, of only .0002 inches or a stress of 1000 lb. per sq. in. if the gauged length is 6 inches and the modulus of elasticity of the steel is 30 000 000. The leg d – e is movable and can be moved along the body of the instrument giving gauge lengths varying from 6 inches to 11 inches. The amount of motion of the lever arm at (a) can be measured either by a micrometer screw with an electric contact or by an Ames dial. It was found that the Ames dial gave quicker and more satisfactory results. To apply the instrument it was necessary to chisel out holes in the concrete to the steel, and then holes about $\frac{3}{64}$-in. in diameter and 3/32-in. deep were drilled into the steel to which the points of the instrument were adjusted. The instrument ordinarily measures to .0002 of an inch, although its performance depends a great deal on the practice and skill of the operator, and upon the cleanness and smoothness of the holes.

Fig. 1



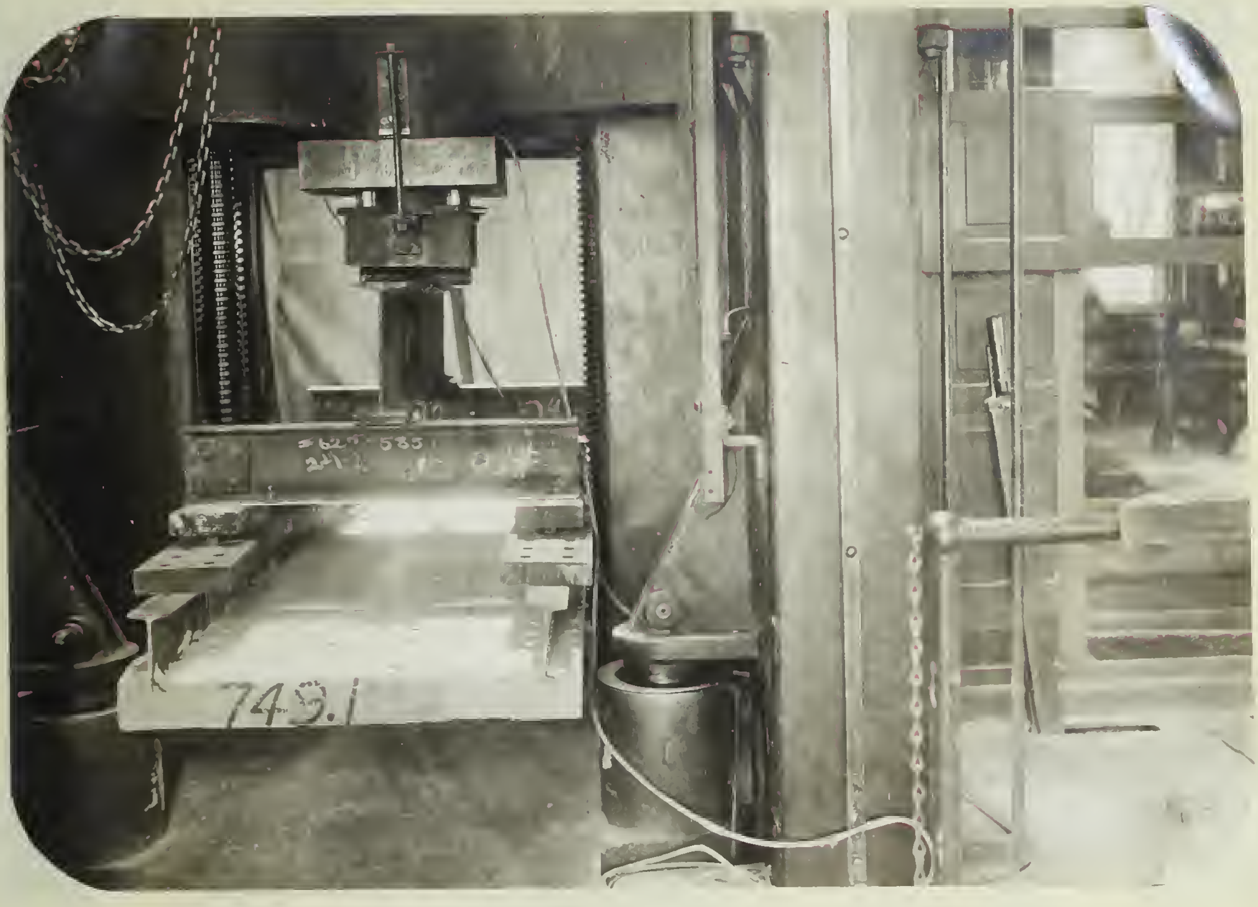
Method of Loading Specimens in the 200 000# Olsen Machine

Fig. 2



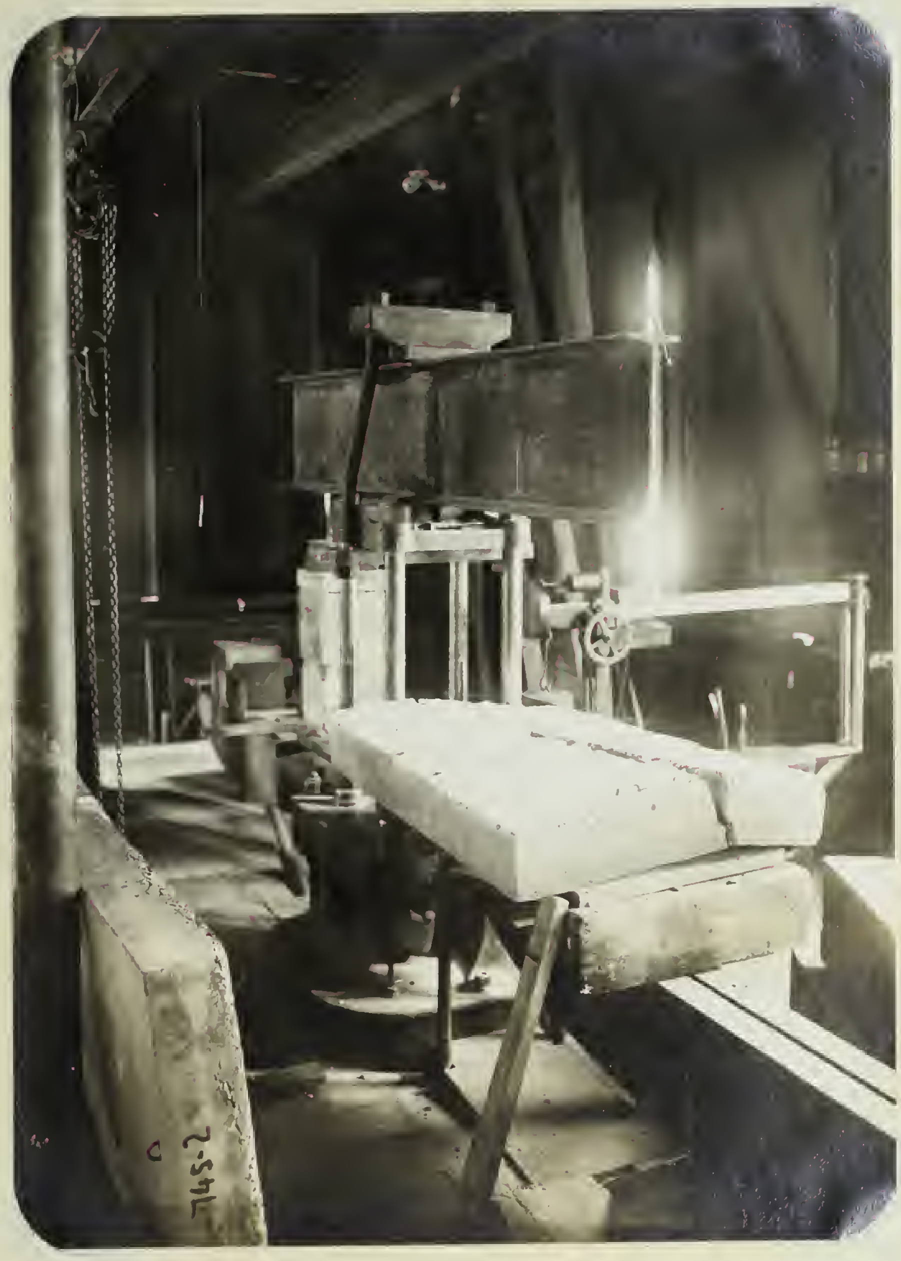
Method of Loading Beams No. 749.1 and 749.2 in Riehle Machine

Fig. 4



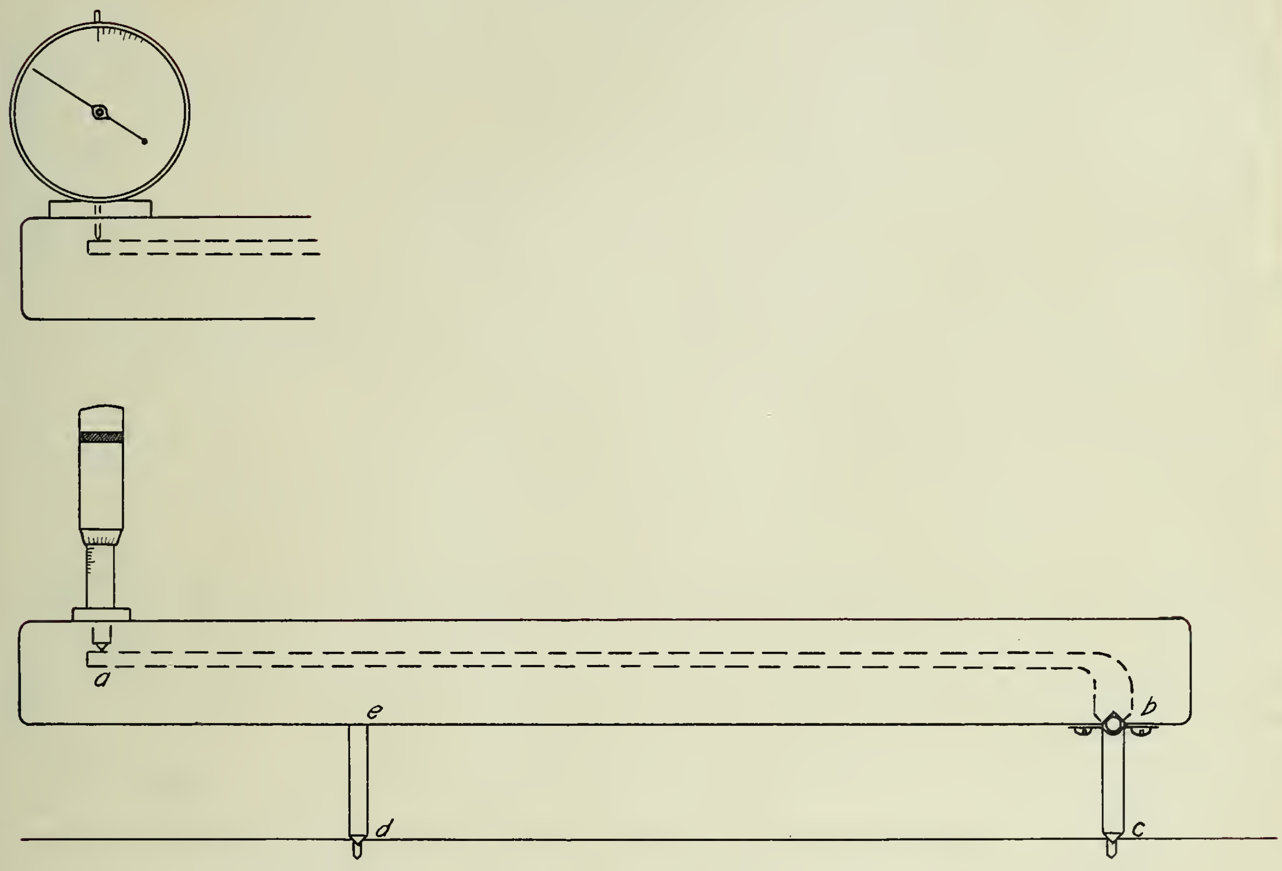
The Riehle Machine

Fig. 5



The Olsen Machine

Fig. 3



Berry Instrument

III EXPERIMENTAL DATA AND DISCUSSION

No.	Width inches	Span inches	Dep to Stee
742.1	24	48	3
742.3	"	"	"
Average			
742.2	"	"	"
742.4	"	"	"
Average			
743.1	36	"	"
743.2	"	"	"
Average			
743.3	"	"	"
743.4	"	"	"
Average			
744.1	"	"	6
744.2	"	"	"
Average			
744.3	"	"	"
744.4	"	"	"
Average			
744.5	"	"	"
744.6	"	"	"
Average			
745.1	"	"	"
745.2	"	"	"
Average			
746.1	"	"	"
746.2	"	"	"
Average			
747.1	"	"	3
747.2	"	"	"
Average			
748.1	"	72	"
748.2	"	"	"
Average			
749.1	96	30	"
749.2	"	"	"
Average			

*The deformation is great

† 16" x 18" pier cast on s

8 -- Summary of General Results of Tests - Table VI

No.	Width inches	Span inches	Depth to Steel	Reinforcement				Date Tested	Age Days	Load		$WQ \div P_1$		Unit Deformation in Steel		Cubes		Manner of Failure	Width of Load ÷ Width of Beam
				Longitudinal		Transverse				1911 Tests	1910 Tests	1911 Tests	1910 Tests	Edge	Center	Age	Strength		
				Description	%	Description	%												
742.1	24	48	3	7-$\frac{7}{8}$"×53"ø	1.07			3-10-11	66	10900		1.00		*Yield	Yield			Tension in steel	0.2
742.3	"	"	"	"	"			3-7-11	63	10700		0.98		.00134	.00154			"	"
Average										10800	10800	0.99	0.99						
742.2	"	"	"	"	"			4-25-11	74	9450		0.87		.00124	.00116			"	0.1
742.4	"	"	"	"	"			5-2-11	81	10900		1.00		.00108	.00106			"	"
Average										10300	11450	0.94	1.05						
743.1	36	"	"	10-$\frac{7}{8}$"×53"ø	1.02			3-11-11	67	11150		0.72		.00106	.00108			As slab	"
743.2	"	"	"	"	"			5-15-11	77	14450		0.93		.00140	.00142			"	"
Average										12800		0.83							
743.3	"	"	"	"	"			3-14-11	70	11900		0.76		.00127	.00207			"	0.2
743.4	"	"	"	"	"			5-15-11	77	16000		1.03		.00133	.00136			"	"
Average										14000	13500	0.89	0.86						
744.1	"	"	6	20-$\frac{7}{8}$"×53"ø	"			3-25-11	63	55700		0.89		.00142	.00161			Diagonal tension	0.5
744.2	"	"	"	"	"			4-29-11	70	63800		1.06		.00155	.00166			Tension in steel	"
Average										59800	55500	0.96	0.82						
744.3	"	"	"	"	"			3-28-11	66	45000		0.72		.00100	.00106			Diagonal tension	0.2
744.4	"	"	"	"	"			5-8-11	70	59000		0.95		.00120	.00126			"	"
Average										52000	39800	0.83	0.61						
744.5	"	"	"	"	"			4-28-11	70	44000		0.70		.00114	.00108			As slab	0.1
744.6	"	"	"	"	"			5-10-11	70	44400		0.71		.00093	.00088			"	"
Average										44200	36000	0.70	0.57						
745.1	"	"	"	"	"	12-$\frac{1}{4}$"×35"ø	0.22	4-19-11	78	47000		0.75		.00108	.00108			Diagonal tension	"
745.2	"	"	"	"	"	"	"	5-11-11	76	57000		0.91		.00119	.00131			"	"
Average										52000	53700	0.83	0.87						
746.1	"	"	"	"	"	12-$\frac{3}{8}$"×35"ø	0.49	4-11-11	78	51700		0.83		.00122	.00117			"	"
746.2	"	"	"	"	"	"	"	5-13-11	78	60000		0.96		.00134	.00143			"	"
Average										55900	59200	0.83	0.95						
747.1	"	"	3	10-$\frac{7}{8}$"×53"ø	"			5-2-11	75	16875		1.08		.00101	.00060			Tension in steel	†0.5
747.2	"	"	"	"	"			5-16-11	74	17300		1.12		.00140	.00095			"	"
Average										17100		1.10							
748.1	"	72	"	10-$\frac{7}{8}$"×75"ø	"			5-5-11	78	10100		0.98		.00185	Yield			"	0.1
748.2	"	"	"	"	"			5-16-11	74	11900		1.15		.00150	.00138			"	"
Average										11000		1.07							
749.1	96	30	"	24-$\frac{1}{4}$"×35"□	0.52			5-20-11	29	23400		0.37		.00004	.00130			" & diag. ten	0.075
749.2	"	"	"	"	"			5-19-11	24	15200		0.24		.00100	Yield			" "	"
Average										19300		0.31							

*The deformation is greater than could be measured by the instrument used, the deformation at the yield point = .00133

† 16"×18" pier cast on slab

The original data obtained in these tests were recorded in a field note book kept by the Engineering Experiment Station. In Table VI are given the ultimate loads and manner of failure of the various beams. Failure by tension in the steel and by diagonal tension are described in Bulletins No. 4 and No. 14 of the University of Illinois Engineering Experiment Station. Failure as a slab is not well defined, but in this thesis the term will be used to mean failure by cracking longitudinally.

9. Load-Stress Diagrams.—The data obtained in regard to stresses are plotted on pages 20 to 48. The diagrams on the lower part of the page show the corresponding stress and loads for various bars of the beam. Stresses in all the bars were not measured. Only enough were measured to show the general distribution across the beam. The curves are irregular for low stresses or as long as the concrete itself takes part of the tension. As soon as the concrete cracks and the steel takes the large part of the tension, the stresses are directly proportional to the load, or the curve is a straight line. The general tendency is for the steel to take very little stress when the load is first applied, and when a point is reached where the concrete cracks, the stress in the steel jumps up suddenly to a point where it holds the load in equilibrium and from that point on is proportional to the load.

The diagrams in the upper part of the page show the general distribution of stresses across the beam. Two points were chosen at which the stresses are plotted. First, the stresses were plotted

for such a load as produced working stresses in the steel, that is about 15 000 lbs. per sq. in. Second, the stresses were plotted for such a load as stressed the steel to its elastic limit, that is about 35 000 lbs. per sq. in. The most noticeable feature of these diagrams is their irregularity. The stress in any particular bar seems to depend upon something else besides the load and the position of the bar in the beam. This is at least true for all the beams which have a greater span than width irrespective of the ratio of the width of load to width of beam. In many cases the stresses in bars at the edges of the beam are greater than the stresses in bars in the center of the beam directly beneath the load. In beams 749.1 and 749.2, where the width is greater than the span, there is a marked variation in stress between the bars at the center of the beam and those at the edges. There is also a noticeable irregularity in the curve due to irregularity in bond, but the stress falls away so rapidly as the bars are removed from the center that the bars at the edges cannot be counted on to take anything like as much stress as the bars at the center do.

10. Manner of Failure.—Although the distribution of stress in beams, where the span is greater than the width, does not seem to be much affected by the ratio of the width of the load to the width of the beam, the manner of failure is. A beam loaded for its full width may fail either by tension in the steel or by diagonal tension, depending upon the ratio of the span to the depth. So that the only difference in effect that concentrating the load would have would be to cause slab failure. All of the beams numbered 743 failed in this manner, and also beams numbers 744.5 and 744.6. Other beams of series number 744 failed by tension in the steel or by

diagonal tension and carried more load than those that failed as a slab.

A small per cent of cross-reinforcing was sufficient to prevent failure as a slab. The diagrams, showing the stresses in the cross-reinforcement of beams number 745 and 746 on pages 34 to 40 show that the stresses are small until the ultimate load is nearly reached when they increase rapidly, which fact shows that slab failure tends to occur suddenly with a small increase of load.

The wide beams, numbered 749, were made to fail in all three ways by applying the load long enough. The primary failure was by tension in the steel in the bars directly under the load. When these yielded, the bars adjacent took the stress until they yielded, a point being finally reached where a longitudinal crack opened, showing a tendency to fail as a slab. On continuing to apply the load, final failure was by diagonal tension, a piece having somewhat the shape of a frustum of a pyramid being punched out. The top of this frustum consisted of the area under and between the loading plates and the bottom of it was a square whose side was about equal to the span.

11. Ultimate Load.—

For the purpose of determining the effect of the width of a beam on its efficiency the ultimate loads will be reduced to a common basis for comparison. The standard for comparison should be a narrow beam loaded over its full width but in this series of tests there was no such beam. However, beams 742.1 and 742.3 failed by tension in the steel and the variation in the stresses from the center to the edge was slight. The load which they carried was, therefore, probably about the same as would have been carried if the width of the load had been equal to the width of the beam and the

average load carried by these beams will be used as the standard for comparison.

For a reinforced concrete beam,

$M = p\ f\ j\ b\ d^2 = KPl$ in which;

M = resisting moment developed.

p = ratio of reinforcement.

b = width of beam.

d = depth of beam.

jd = arm of resisting couple.

K = a constant dependent upon the method of loading.

P = total load carried by the beam.

l = span of the beam.

Let M_1 be the resisting moment for the average beam of series 742.1 and 742.3, and

$$M_1 = p_1\ f_1\ j_1\ b_1\ d_1^2 = K_1P_1l_1$$

$$\frac{M}{M_1} = \frac{pfjbd^2}{p_1f_1j_1b_1d_1^2} = \frac{KPl}{K_1P_1l_1}$$

$$P = P_1\frac{K_1l_1}{K\ l} \times \frac{p\ f\ j\ b\ d^2}{p_1f_1j_1b_1d_1^2} = P_1\frac{K_1l_1}{K\ l} \times \frac{A\ f\ j\ d}{A_1f_1j_1d_1}$$

This equation for P gives the load which should be carried by any beam in terms of the load P_1 carried by the standard beam. If W is the load actually carried by any beam, its efficiency may be represented by the term $\frac{W}{P} = \frac{W}{P_1} \times \frac{Kl}{K_1l_1} \times \frac{p_1f_1j_1b_1d_1^2}{pfjbd^2}$. In the following table is given for the various series of beams, the values of the coefficient $\frac{Kl}{K_1l_1} \times \frac{p_1f_1j_1b_1d_1^2}{pfjbd^2}$ in which for all cases it is assumed that

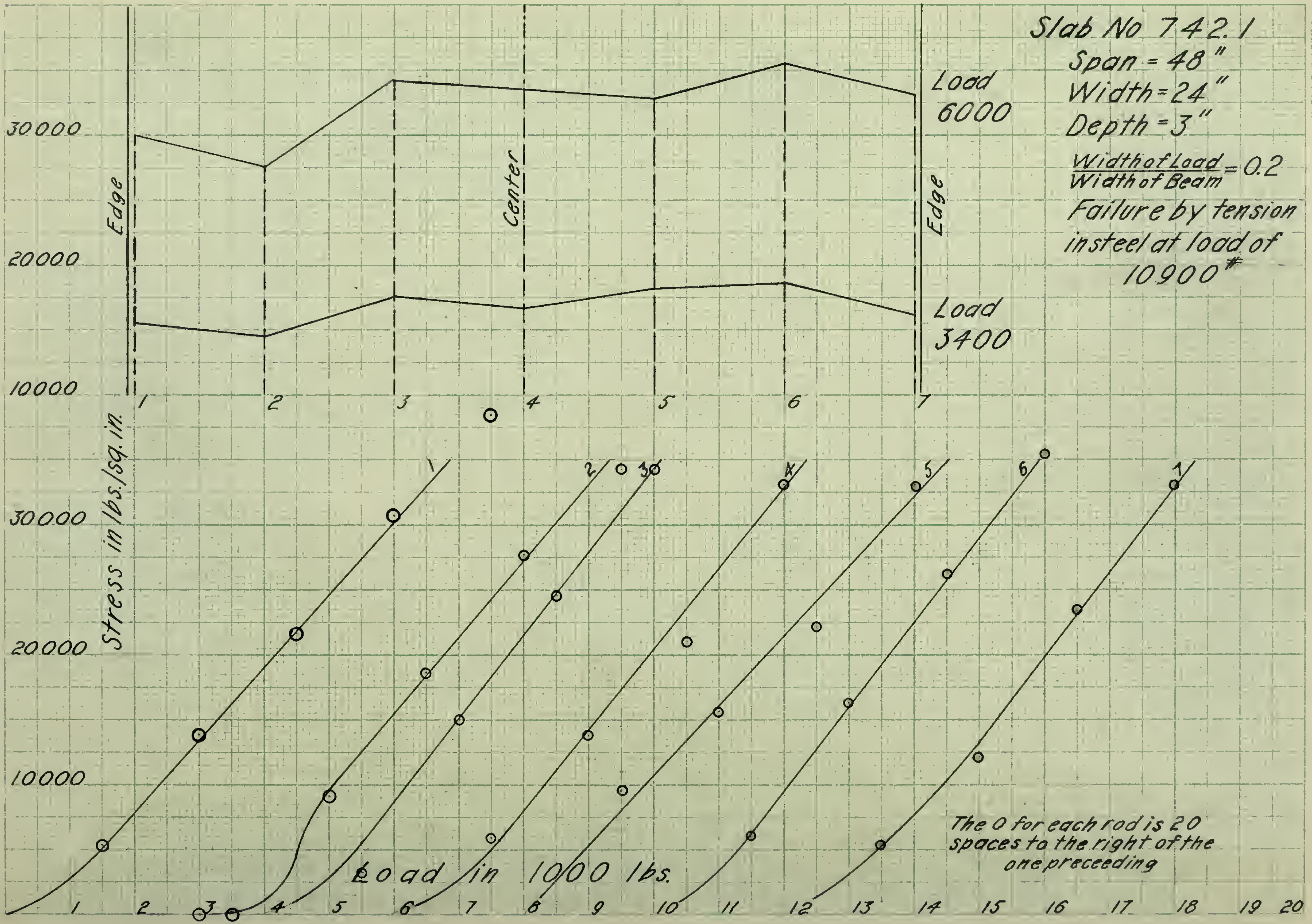
$$f = f_1$$

Series	742.1-4	743	744	745	746	747	748	749
Q	1	.7	.175	.175	.175	0.7	1.05	.4

For convenience call the **coefficient**

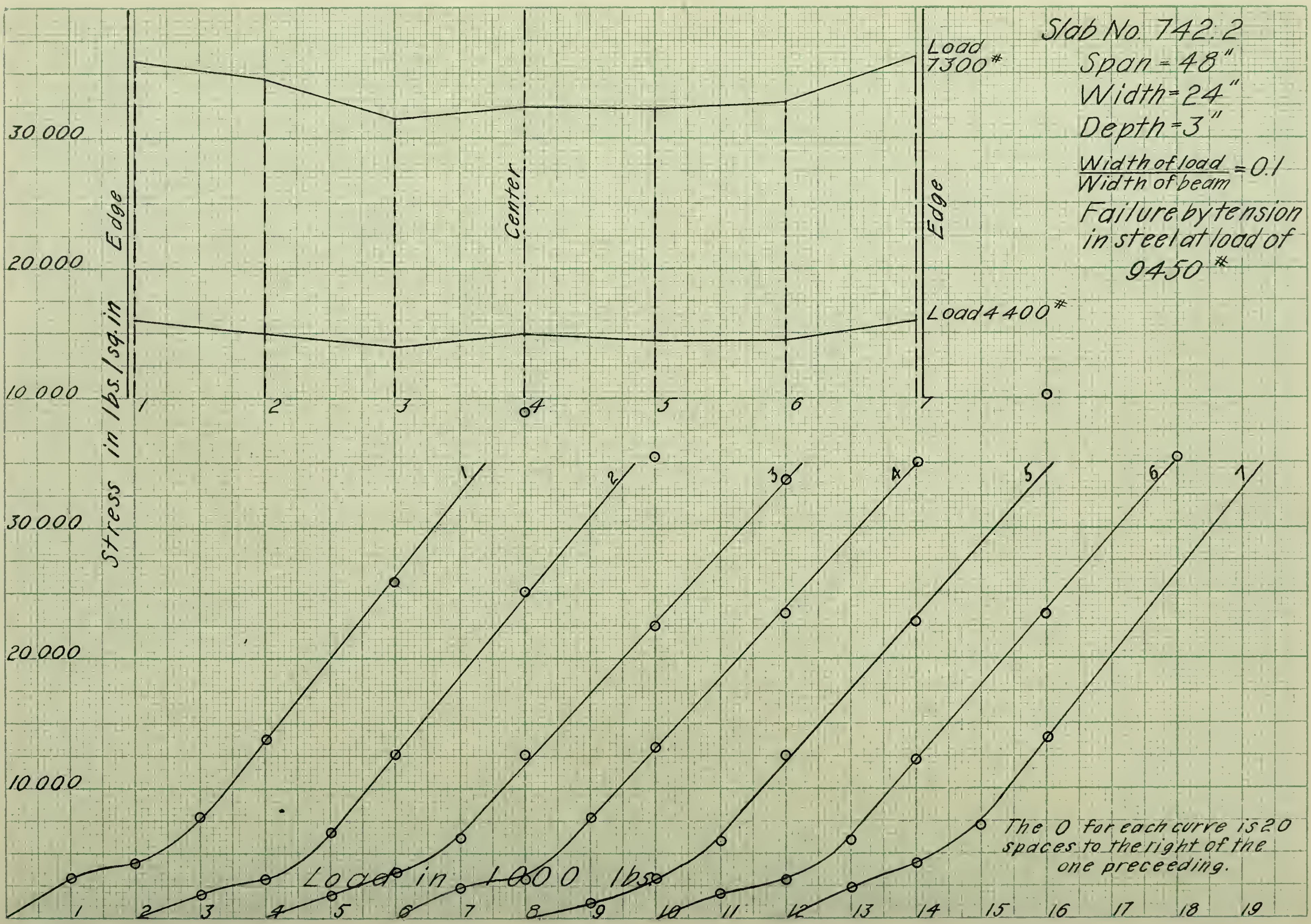
$\frac{Kl}{K_1 l_1} \times \frac{p_1 f_1 j_1 b_1 d_1^2}{pfjbd^2} = Q$. Then the efficiency of a beam may be represented by the ratio $\frac{W}{P} = \frac{WQ}{P_1}$ .. In the summary sheet (Table VI page 14) a column is headed $\frac{WQ}{P_1}$ giving the efficiencies for the various beams of this series.

Reference to this table shows that when the full strength of the steel was developed, the beam gave the greatest efficiency. Where a beam failed by diagonal tension or as a slab the efficiency was less. The efficiencies for beams numbered 749 show that only a portion of the strength of the beam was developed. The use of cross-reinforcement, by preventing slab failure, enabled beams number 745 and 746 to take higher load than beams of the same dimensions which failed by slab action. But the results do not show the necessity of cross-reinforcement except as a matter of extra precaution, since some of the beams of the same dimensions as those having cross-reinforcement, did not fail as a slab, and carried higher load than those having cross-reinforcement.



Slab No 742.1
Span = 48"
Width = 24"
Depth = 3"
$\frac{\text{Width of Load}}{\text{Width of Beam}} = 0.2$
Failure by tension in steel at load of 10900#

The 0 for each rod is 20 spaces to the right of the one preceeding


Slab No. 742.2
Span = 48"
Width = 24"
Depth = 3"
Width of load / Width of beam = 0.1
Failure by tension in steel at load of 9450 #
Load 7300 #
Load 4400 #
Edge
Center
Edge
Stress in lbs./sq.in
30.000
20.000
10.000
30.000
20.000
10.000
1
2
3
4
5
6
7
Load in 1.000 lbs.
1
2
3
4
5
6
7
8
9
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14
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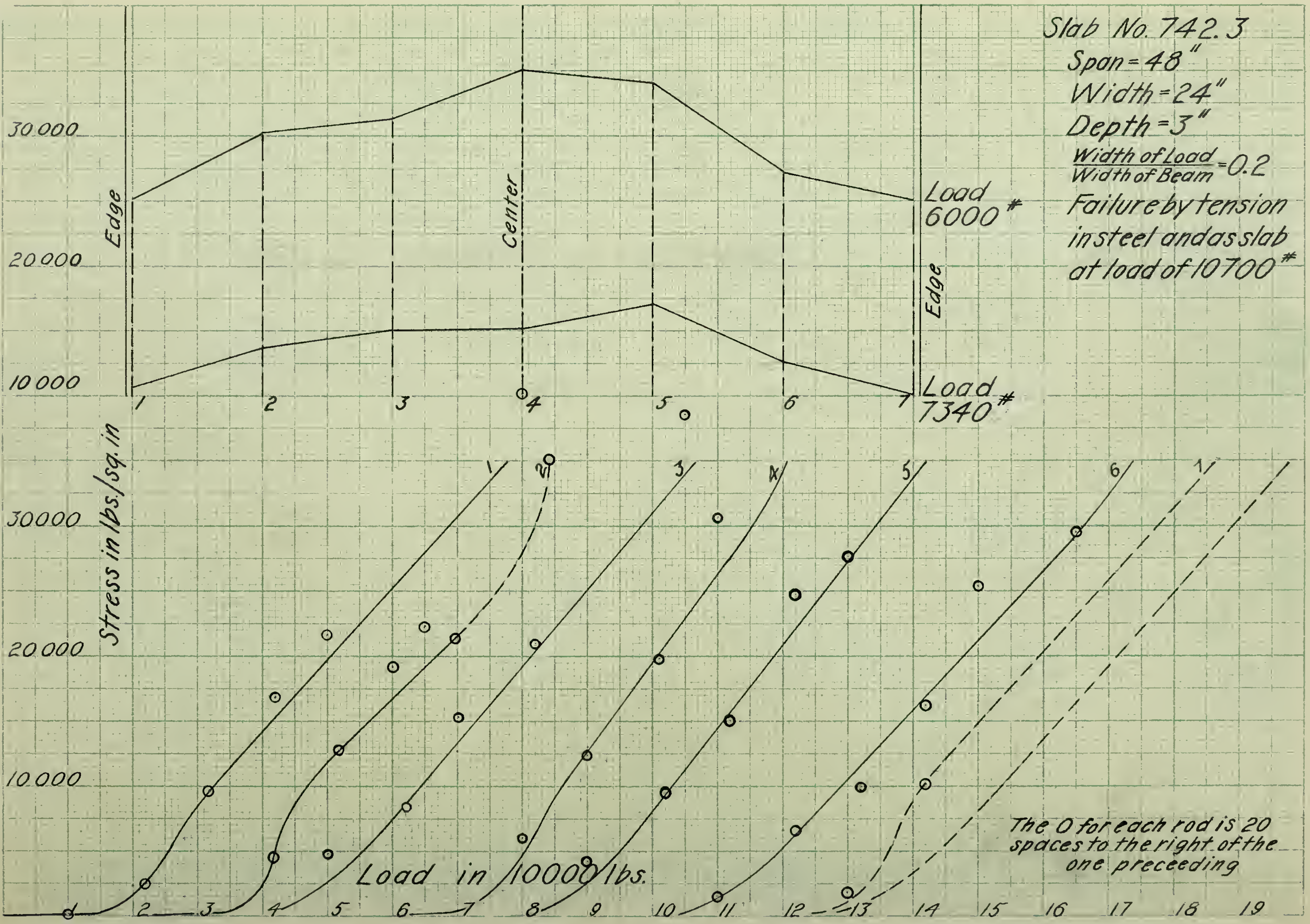
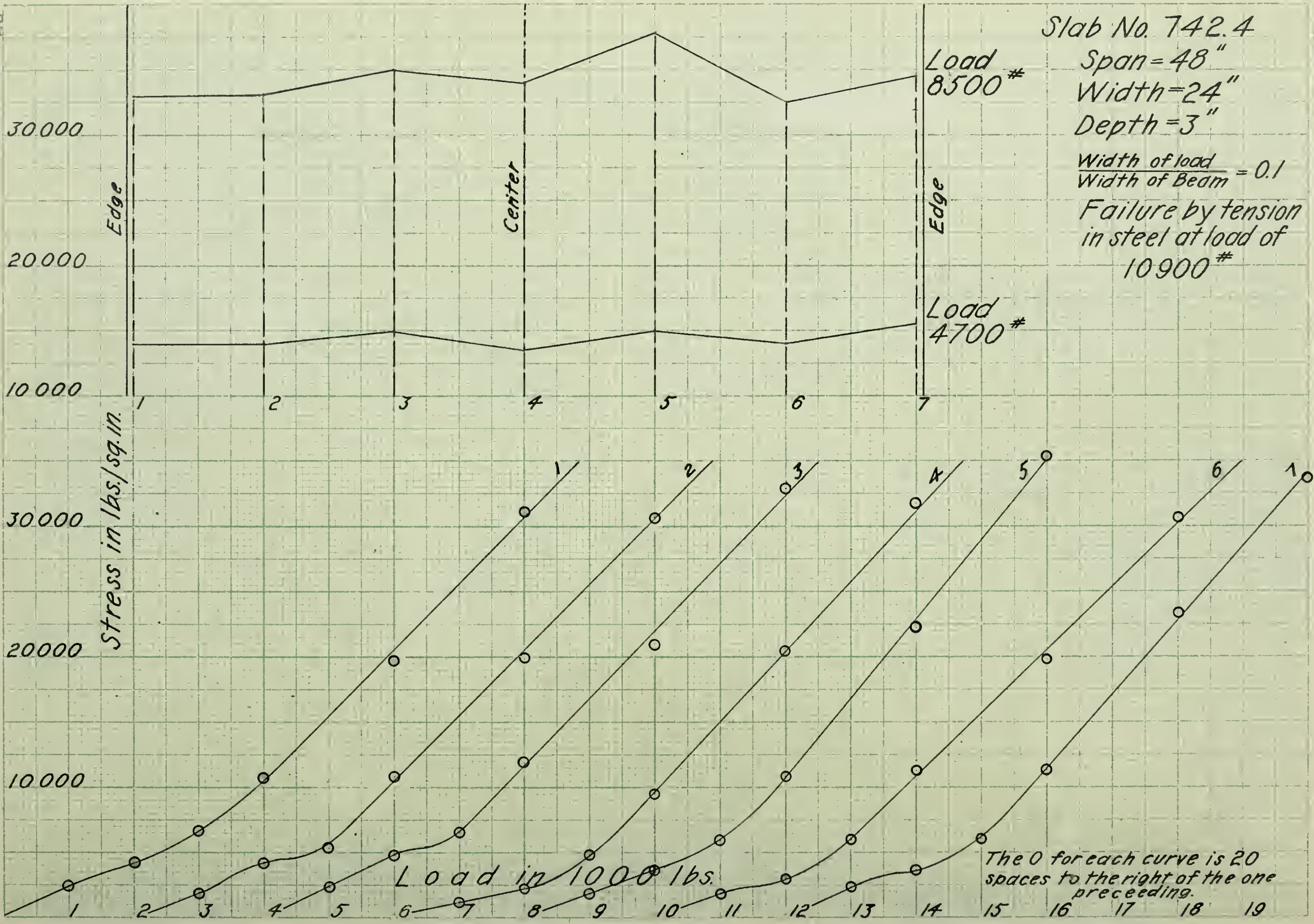
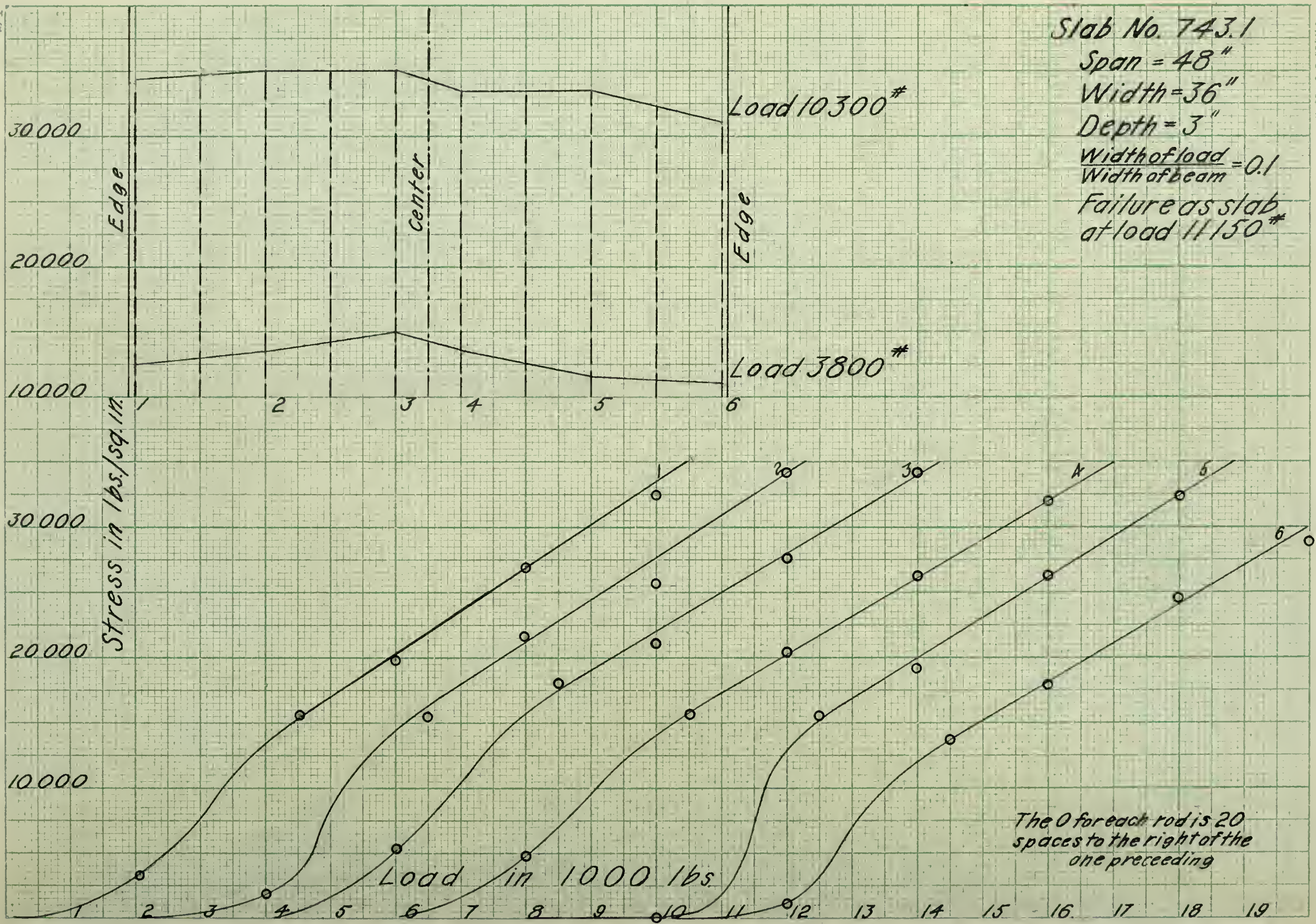
17
18
19
The 0 for each curve is 20 spaces to the right of the one preceeding.



Slab No. 742.3
Span = 48"
Width = 24"
Depth = 3"
$\frac{\text{Width of Load}}{\text{Width of Beam}} = 0.2$
Failure by tension in steel and as slab at load of 10700#

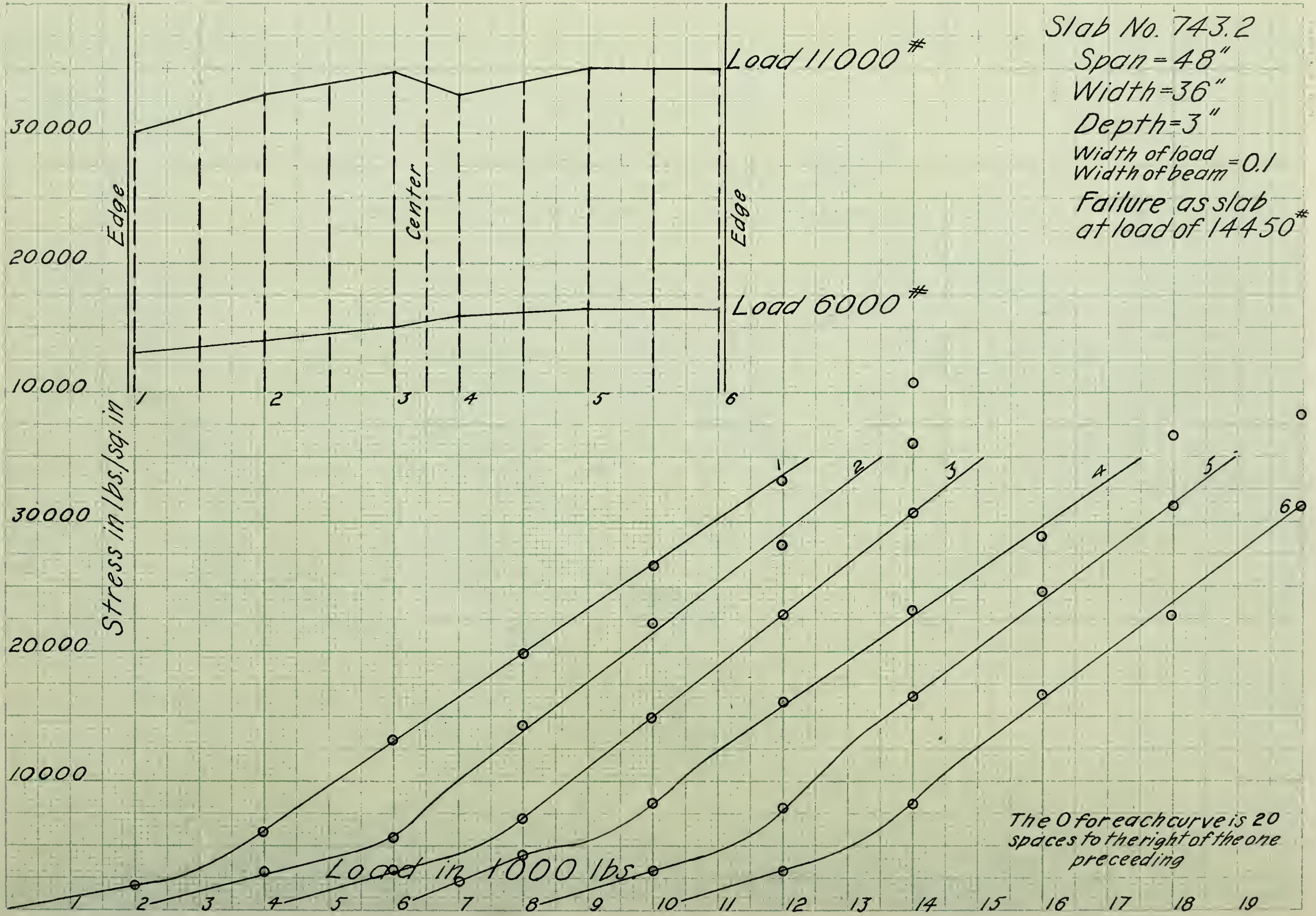
The 0 for each rod is 20 spaces to the right of the one preceeding

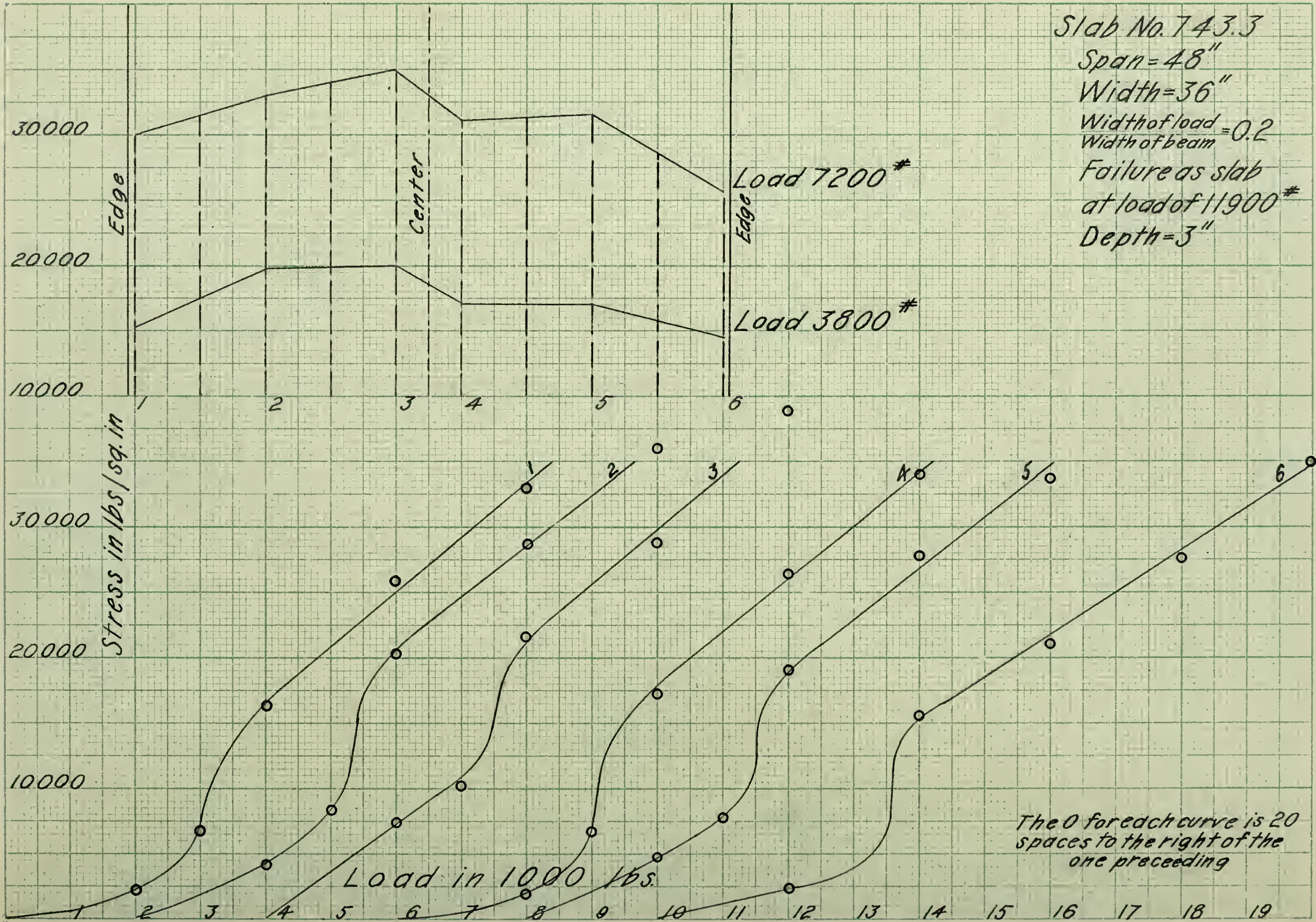

Slab No. 742.4
Span = 48"
Width = 24"
Depth = 3"
Width of load / Width of Beam = 0.1
Failure by tension in steel at load of 10900#
Load 8500#
Load 4700#
Edge
Center
Edge
30000
20000
10000
1
2
3
4
5
6
7
Stress in lbs./sq.in.
30000
20000
10000
1
2
3
4
5
6
1
Load in 1000 lbs.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
The 0 for each curve is 20 spaces to the right of the one preceeding.



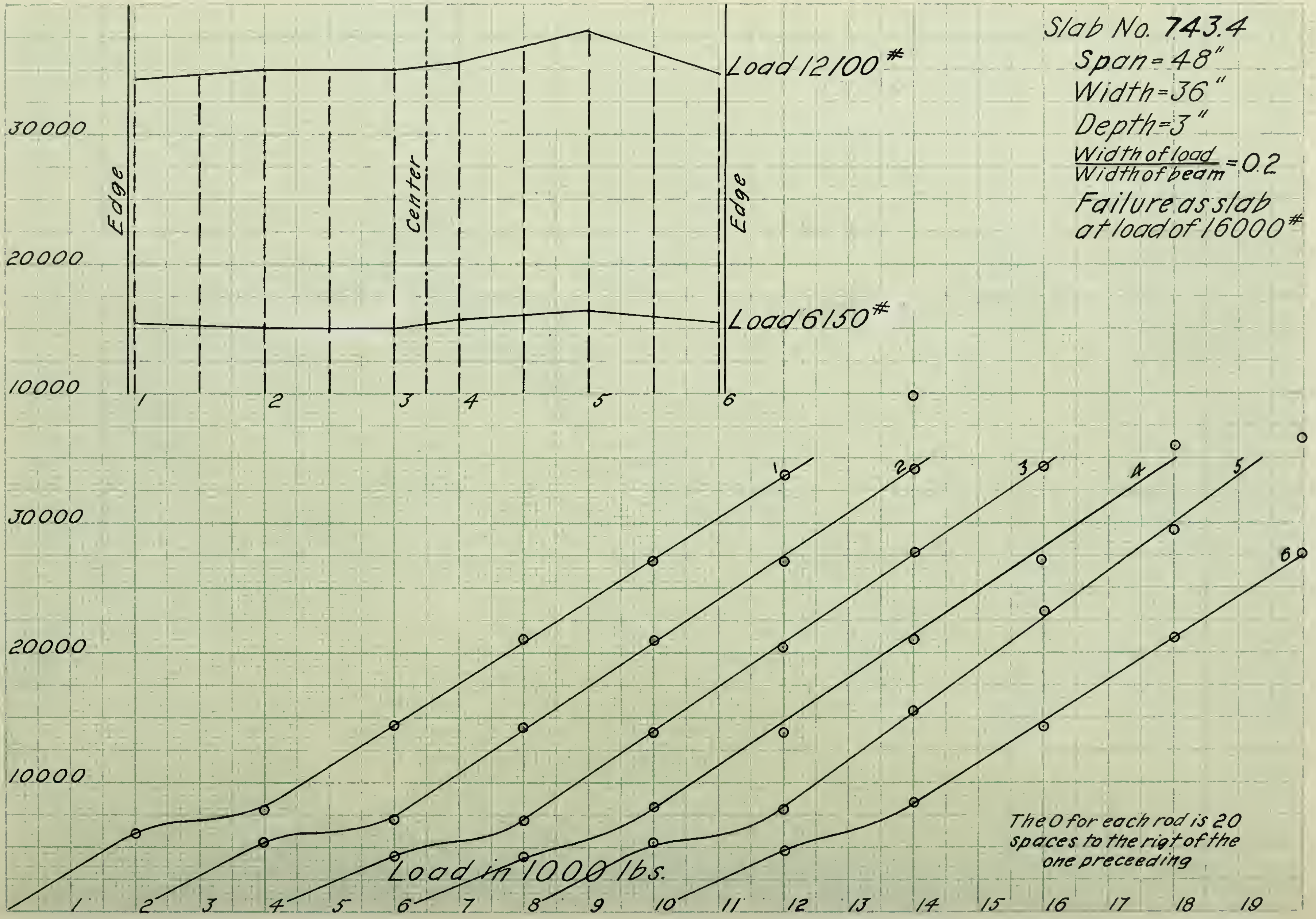
Slab No. 743.1
Span = 48"
Width = 36"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure as slab at load 11150#

The 0 for each rod is 20 spaces to the right of the one preceeding


Slab No. 743.2
Span = 48"
Width = 36"
Depth = 3"
Width of load / Width of beam = 0.1
Failure as slab at load of 14450#
Load 11000#
Load 6000#
Edge
Center
Edge
1
2
3
4
5
6
30000
20000
10000
Stress in lbs./sq. in
30000
20000
10000
1
2
3
4
5
6
Load in 1000 lbs.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
The 0 for each curve is 20 spaces to the right of the one preceeding

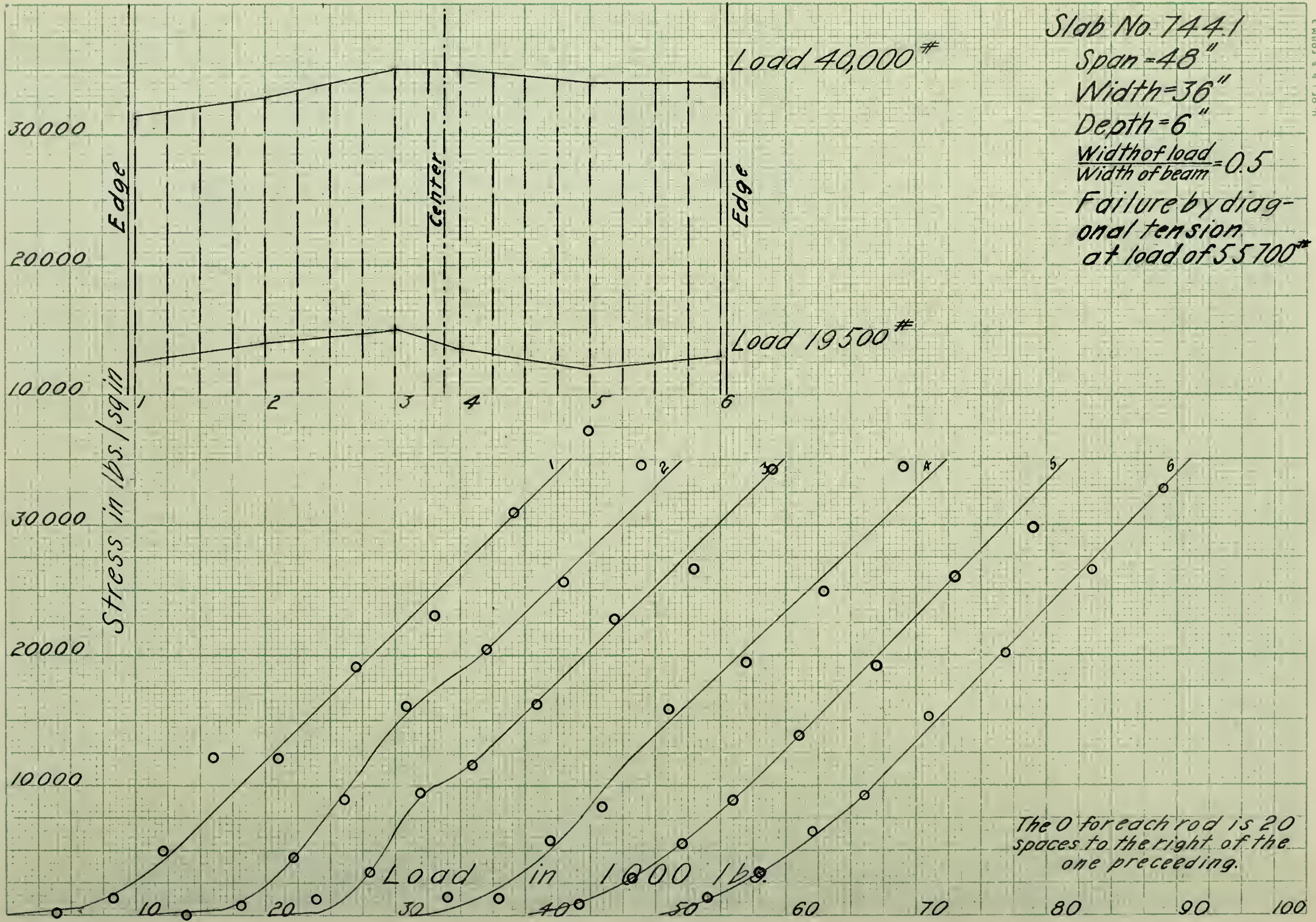


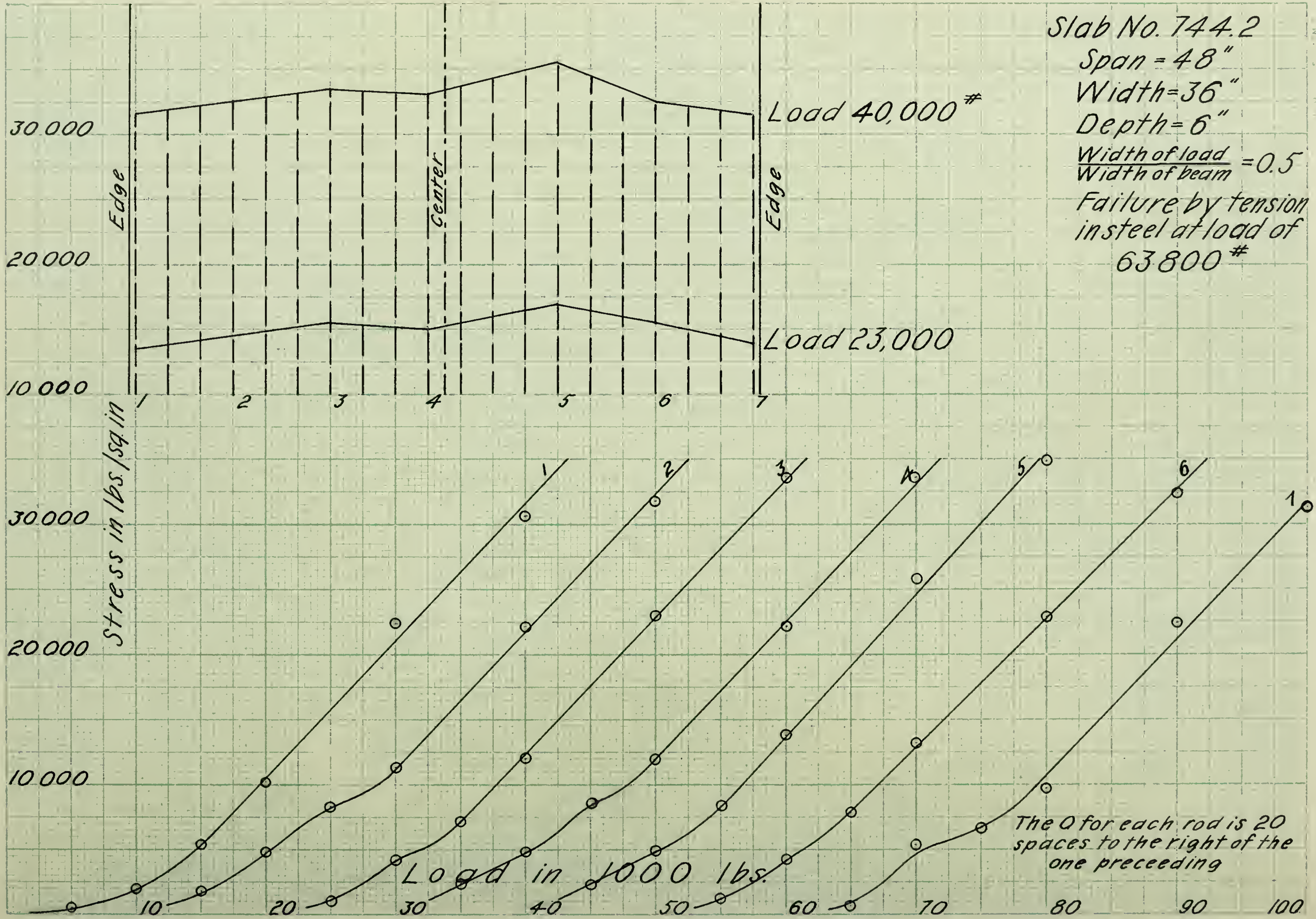
U. OF I. S. B. FORM 3



Slab No. 743.4
Span = 48"
Width = 36"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.2$
Failure as slab at load of 16000#

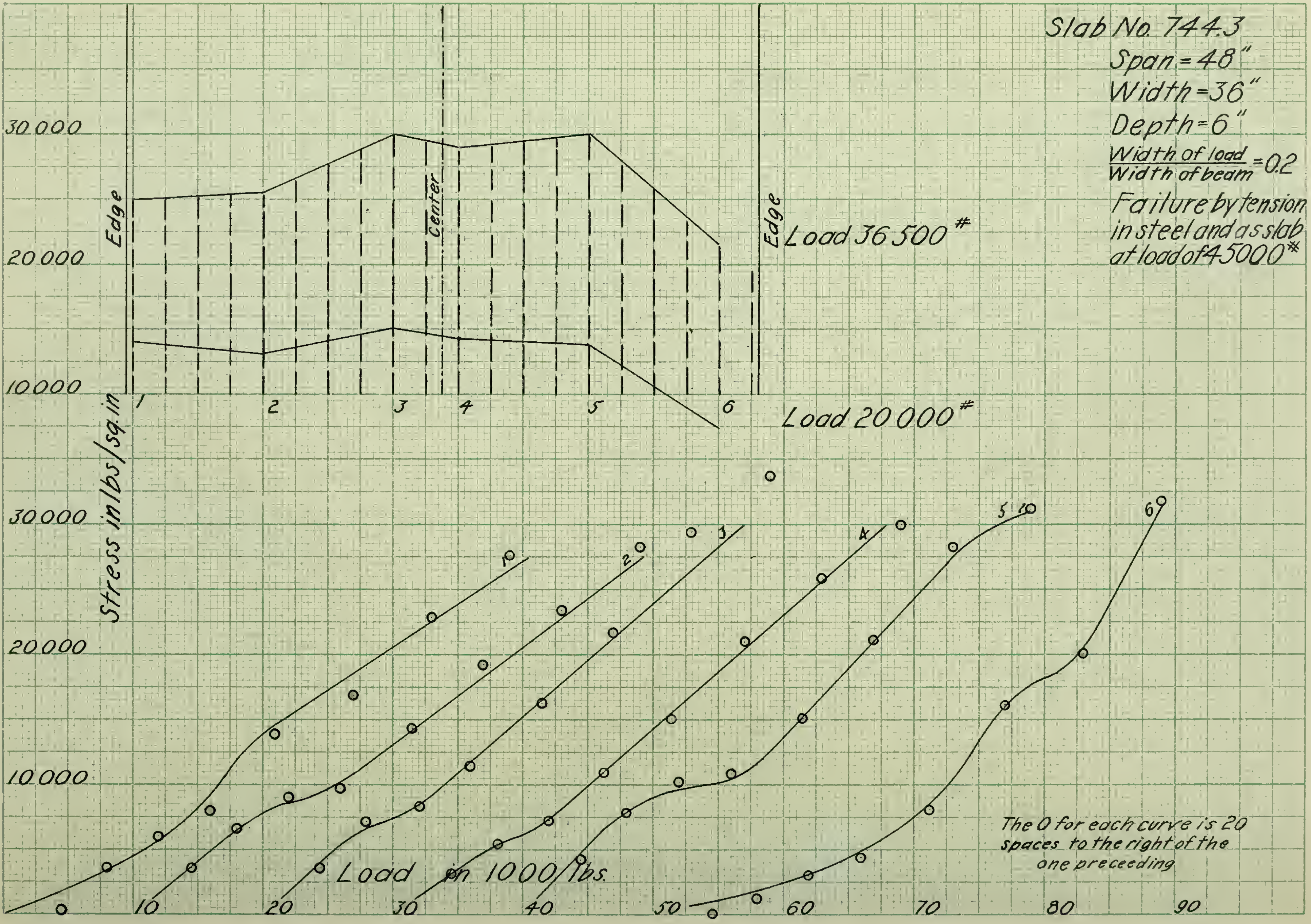
The 0 for each rod is 20 spaces to the rigt of the one preceeding


Slab No 744.1
Span=48"
Width=36"
Depth=6"
$\frac{\text{Width of load}}{\text{Width of beam}}=0.5$
Failure by diagonal tension at load of 55700#
Load 40,000#
Load 19500#
Edge
Center
Edge
1
2
3
4
5
6
30000
20000
10000
Stress in lbs./sqin
30000
20000
10000
1
2
3
4
5
6
Load in 1000 lbs.
10
20
30
40
50
60
70
80
90
100
The 0 for each rod is 20 spaces to the right of the one preceeding.
U. OF I. & E. FORM 3



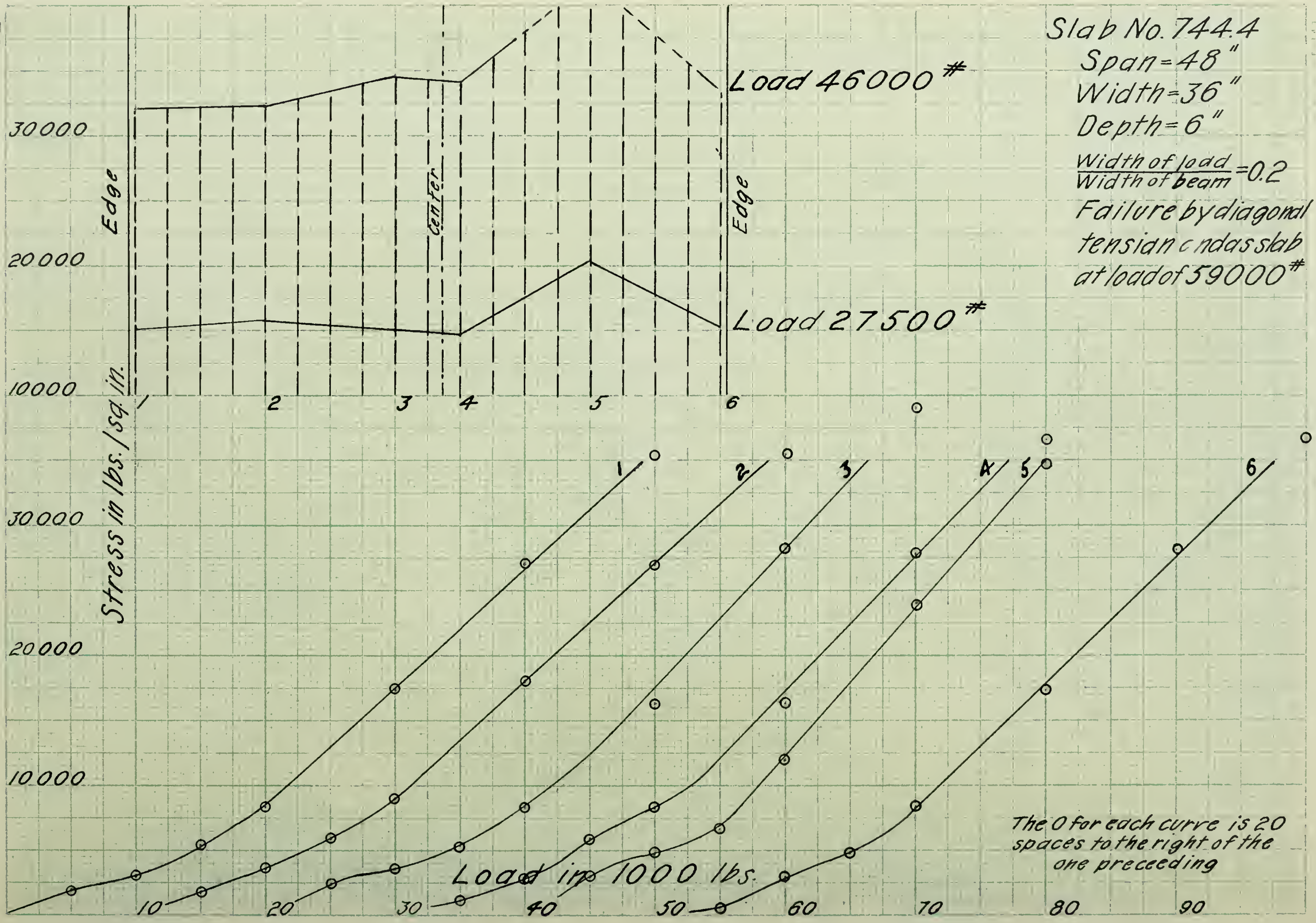
Slab No. 744.2
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.5$
Failure by tension in steel at load of 63800 #

The 0 for each rod is 20 spaces to the right of the one preceeding



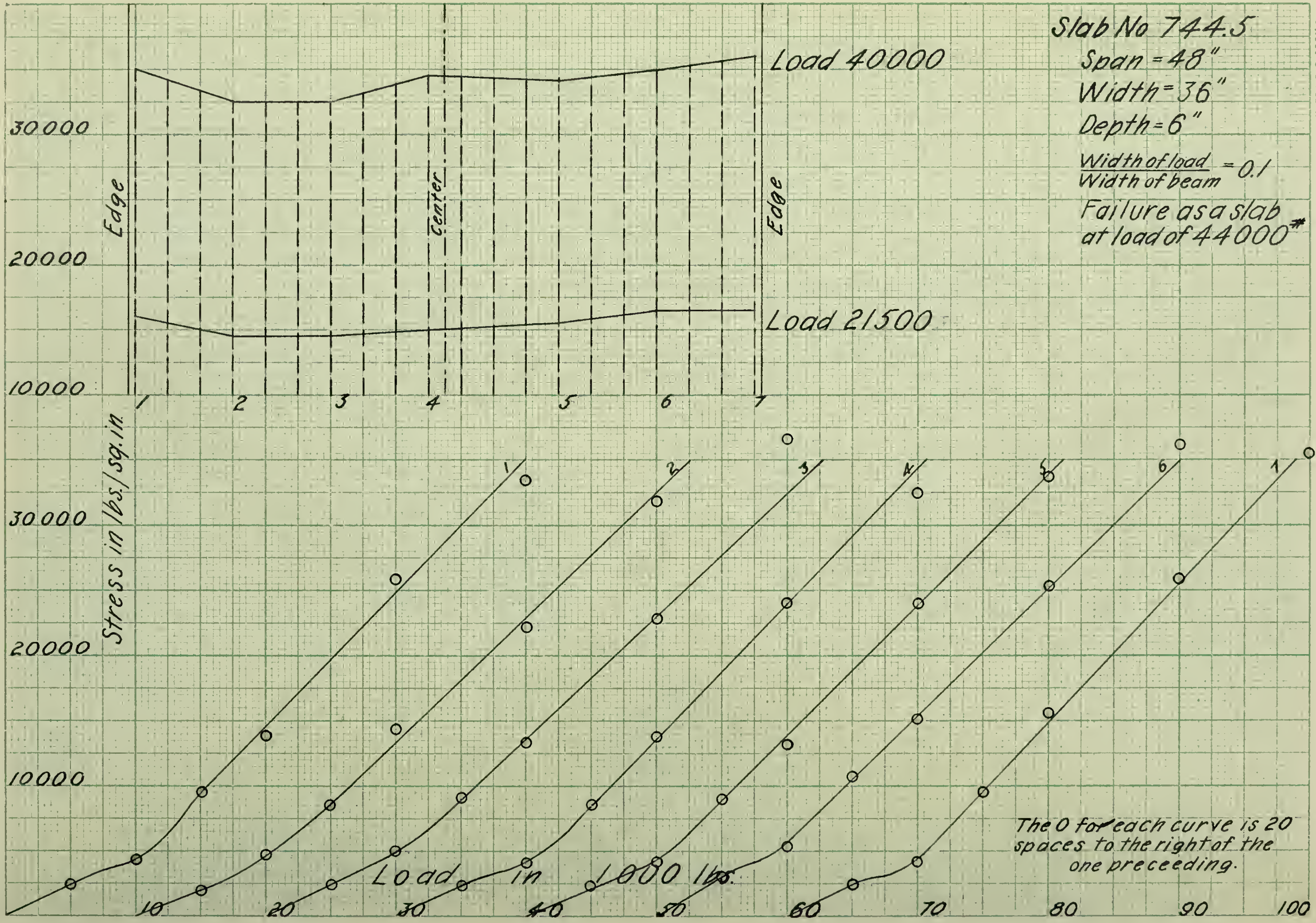
Slab No. 744.3
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.2$
Failure by tension in steel and as slab at load of 45000#

The 0 for each curve is 20 spaces to the right of the one preceeding



Slab No. 744.4
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.2$
Failure by diagonal tensian andas slab at load of 59000#

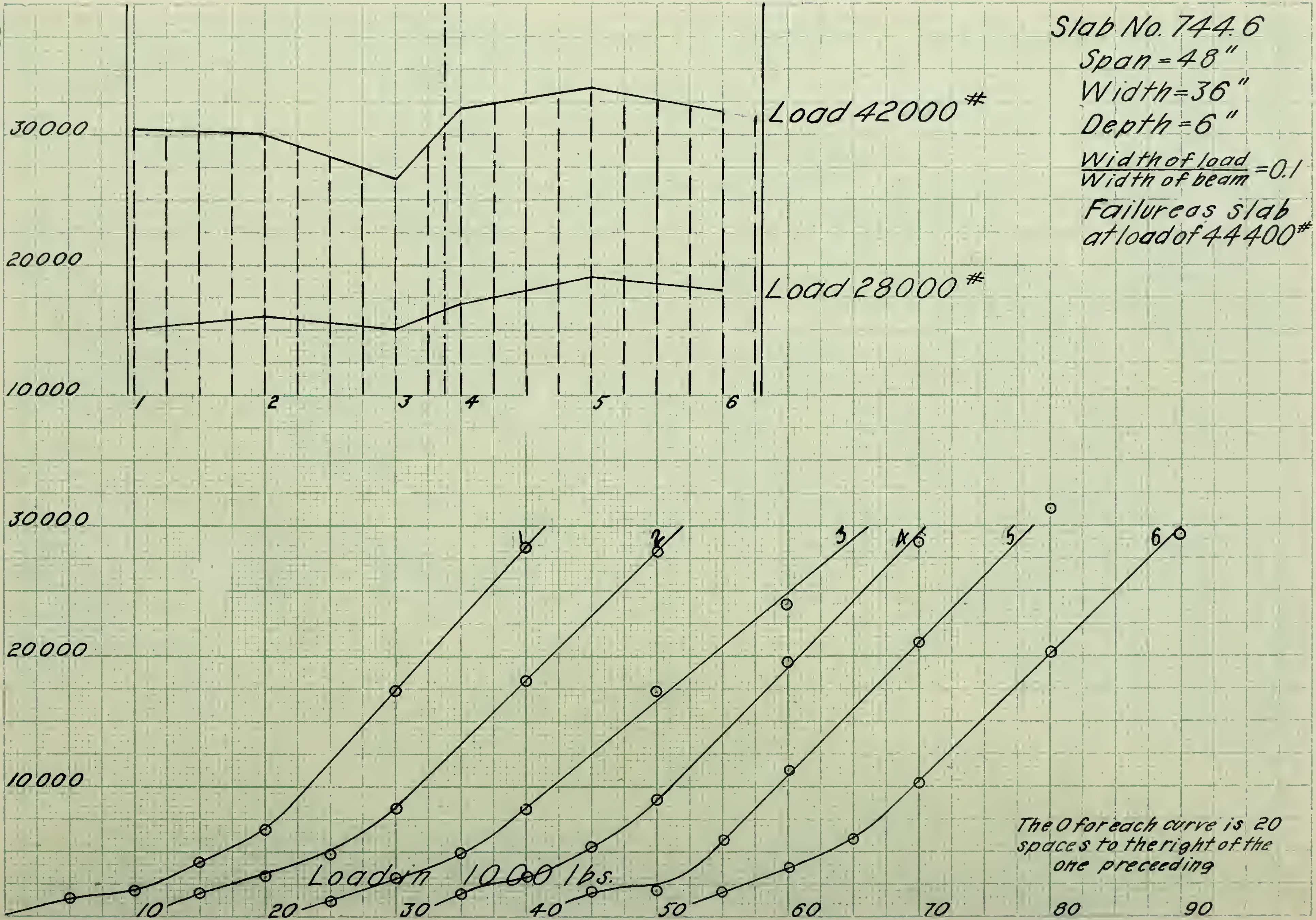
The 0 for each curve is 20 spaces to the right of the one preceeding



Slab No 744.5
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure as a slab at load of 44000#

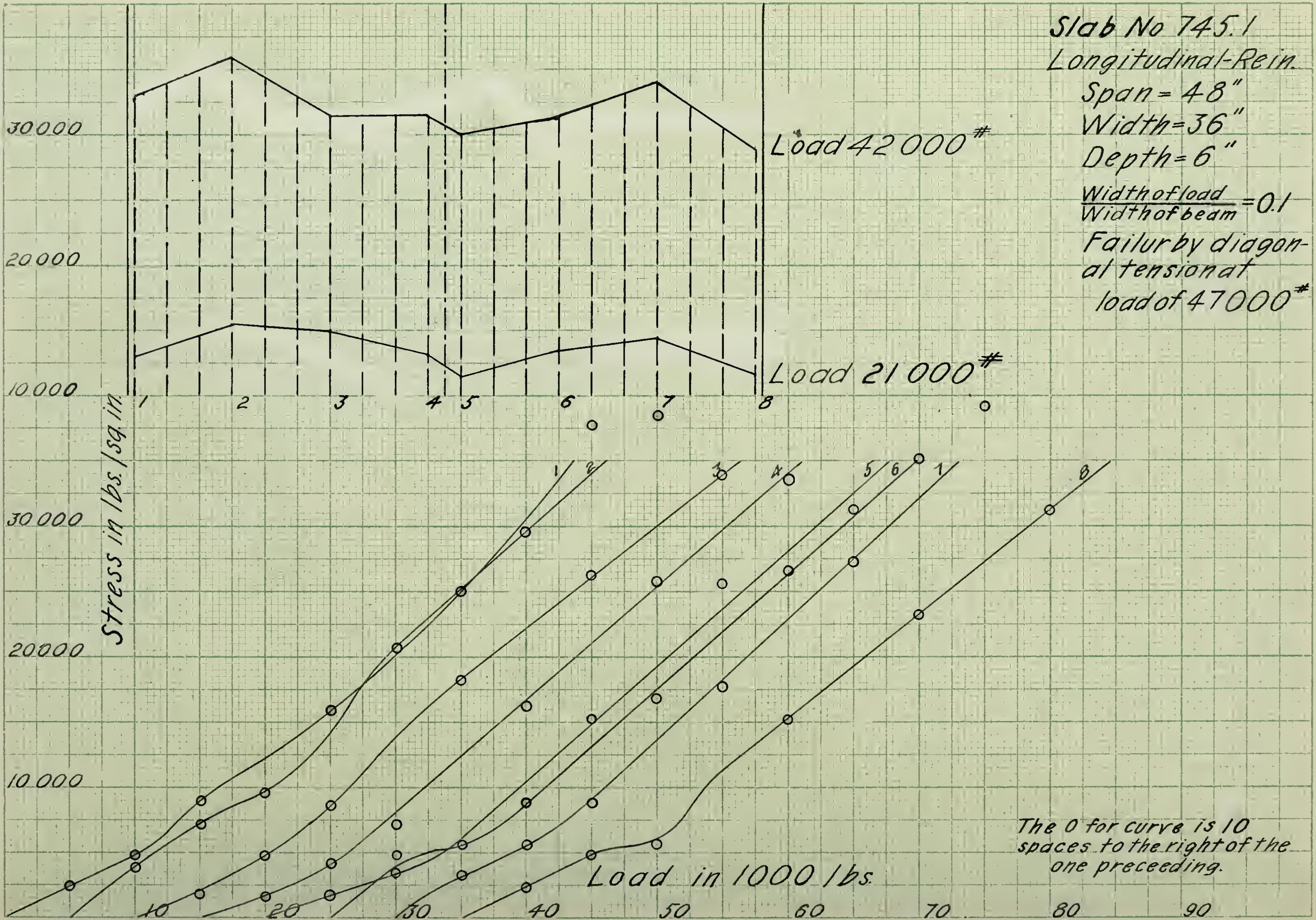
The 0 for each curve is 20 spaces to the right of the one preceeding.

U OF I E S FORM 3



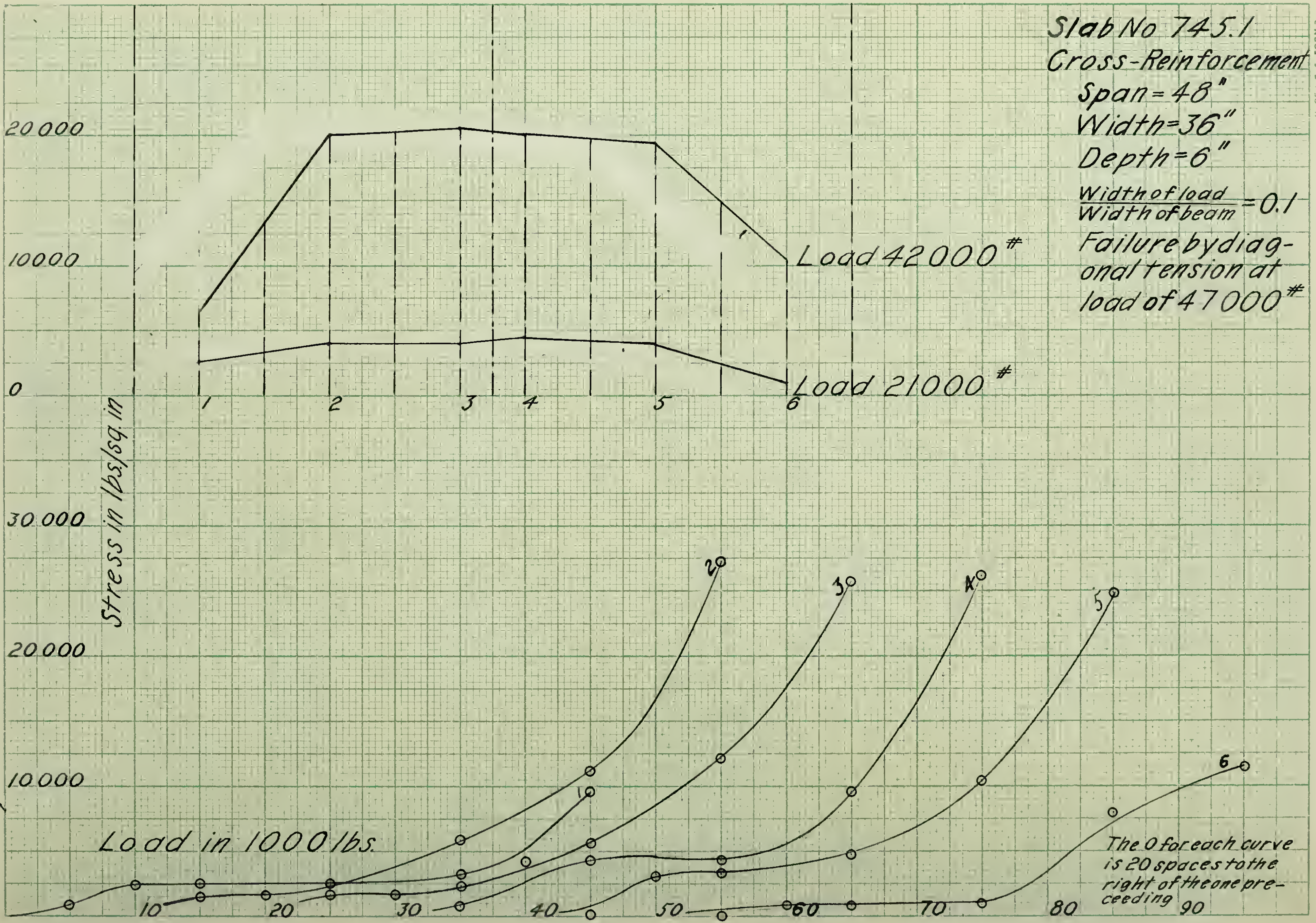
Slab No. 744.6
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure as slab at load of 44400#

The 0 for each curve is 20 spaces to the right of the one preceeding



Slab No 745.1
Longitudinal-Rein.
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failur by diagonal tension at load of 47000#

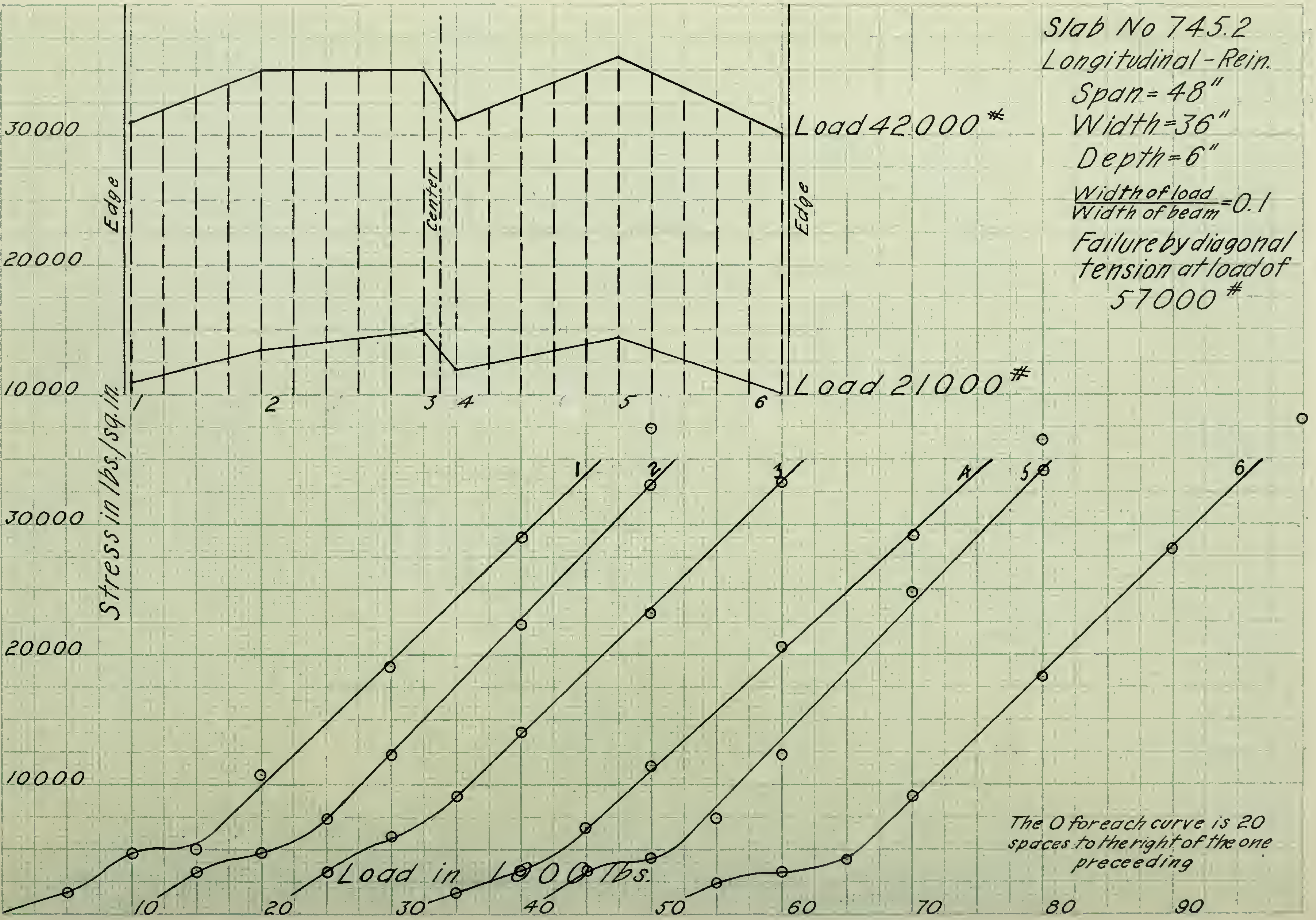
The 0 for curve is 10 spaces to the right of the one preceeding.

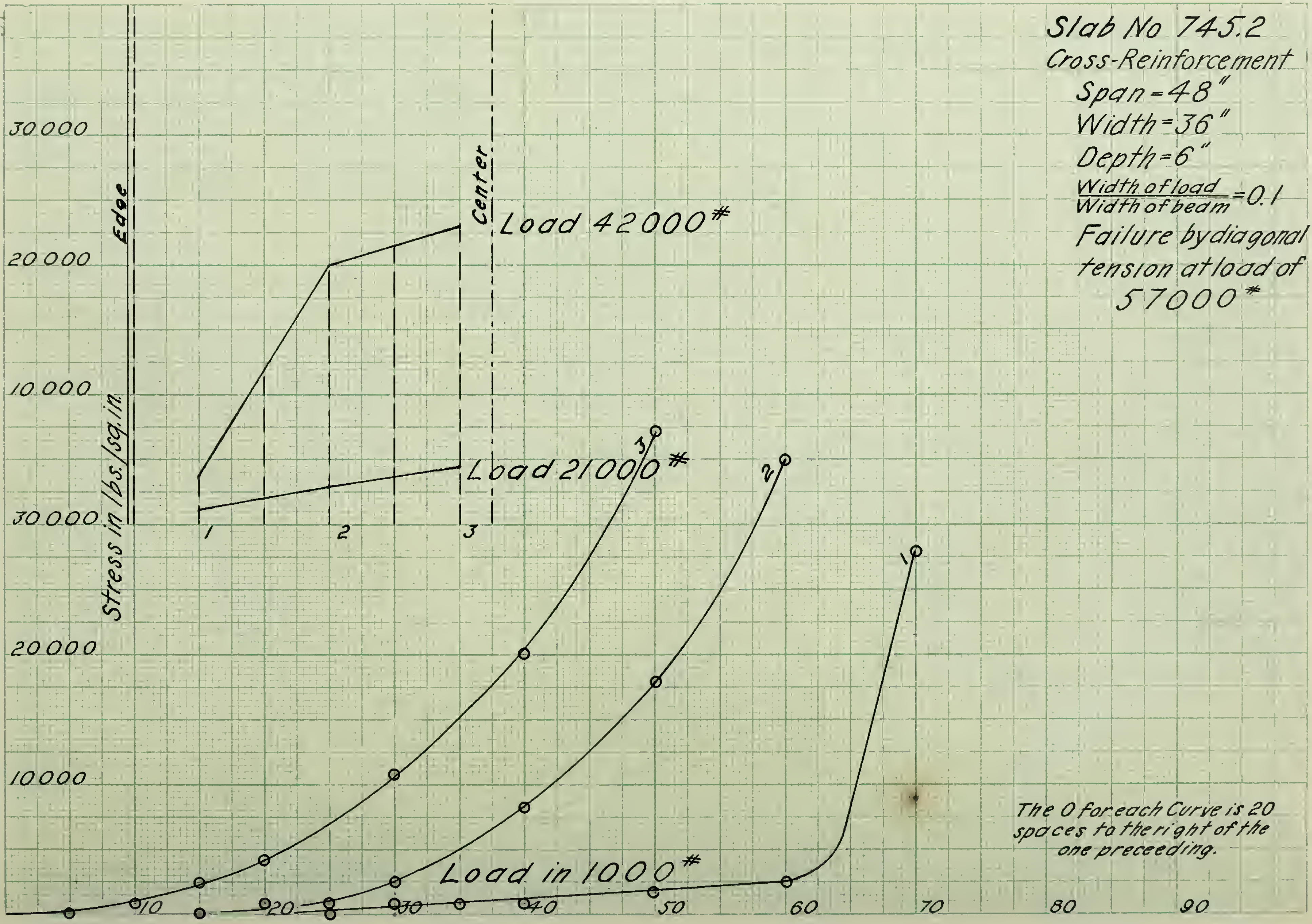


Slab No 745.1
Cross-Reinforcement
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure by diagonal tension at load of 47000#

The 0 for each curve is 20 spaces to the right of the one preceeding

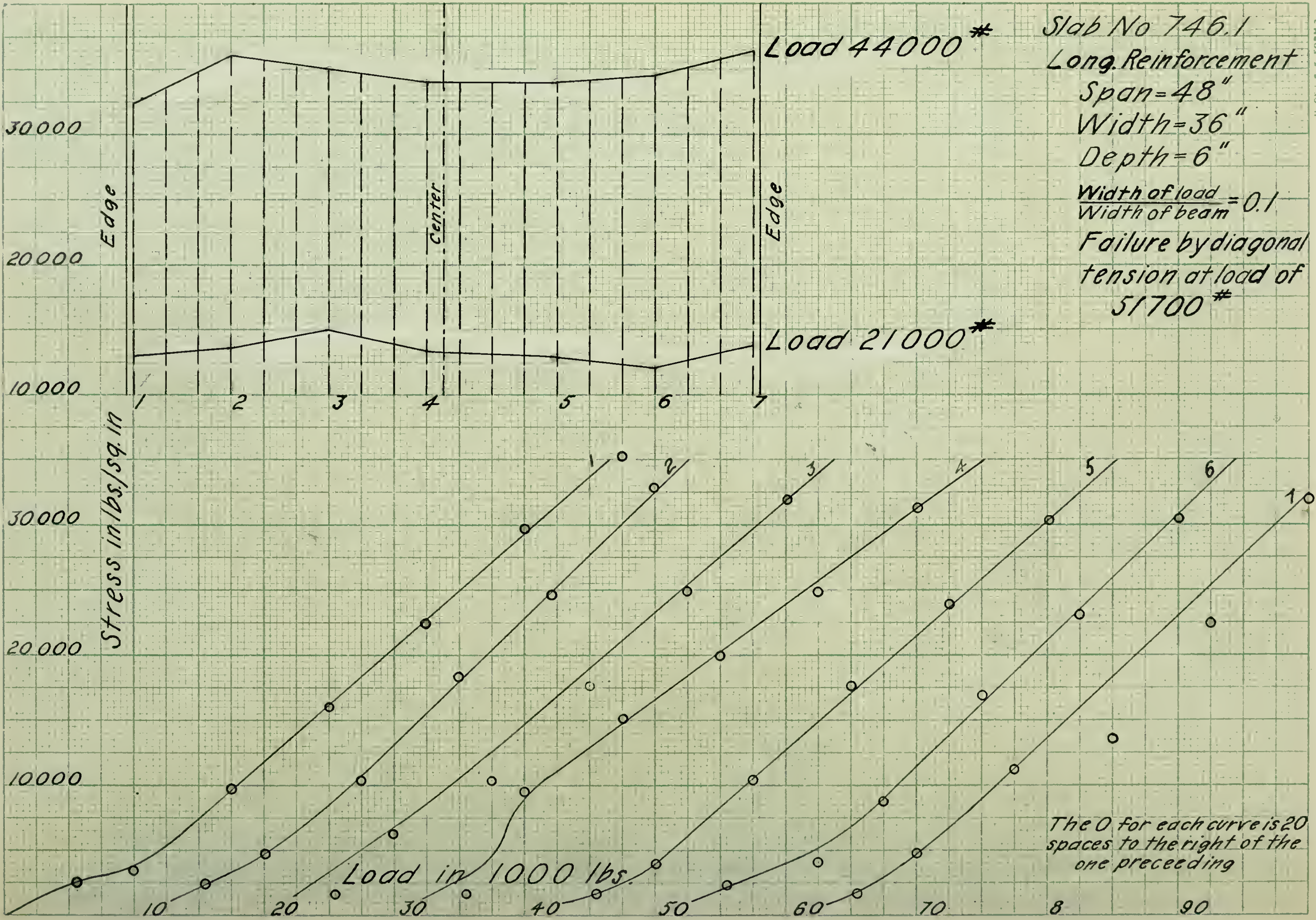
U OF I S S FORM 3


Slab No 745.2
Longitudinal-Rein.
Span = 48"
Width = 36"
Depth = 6"
Width of load / Width of beam = 0.1
Failure by diagonal tension at load of 57000 #
Load 42000 #
Load 21000 #
Edge
Center
Edge
1
2
3
4
5
6
30000
20000
10000
30000
20000
10000
Stress in lbs./sq.in.
Load in 1000 lbs.
10
20
30
40
50
60
70
80
90
1
2
3
4
5
6
The 0 for each curve is 20 spaces to the right of the one preceeding



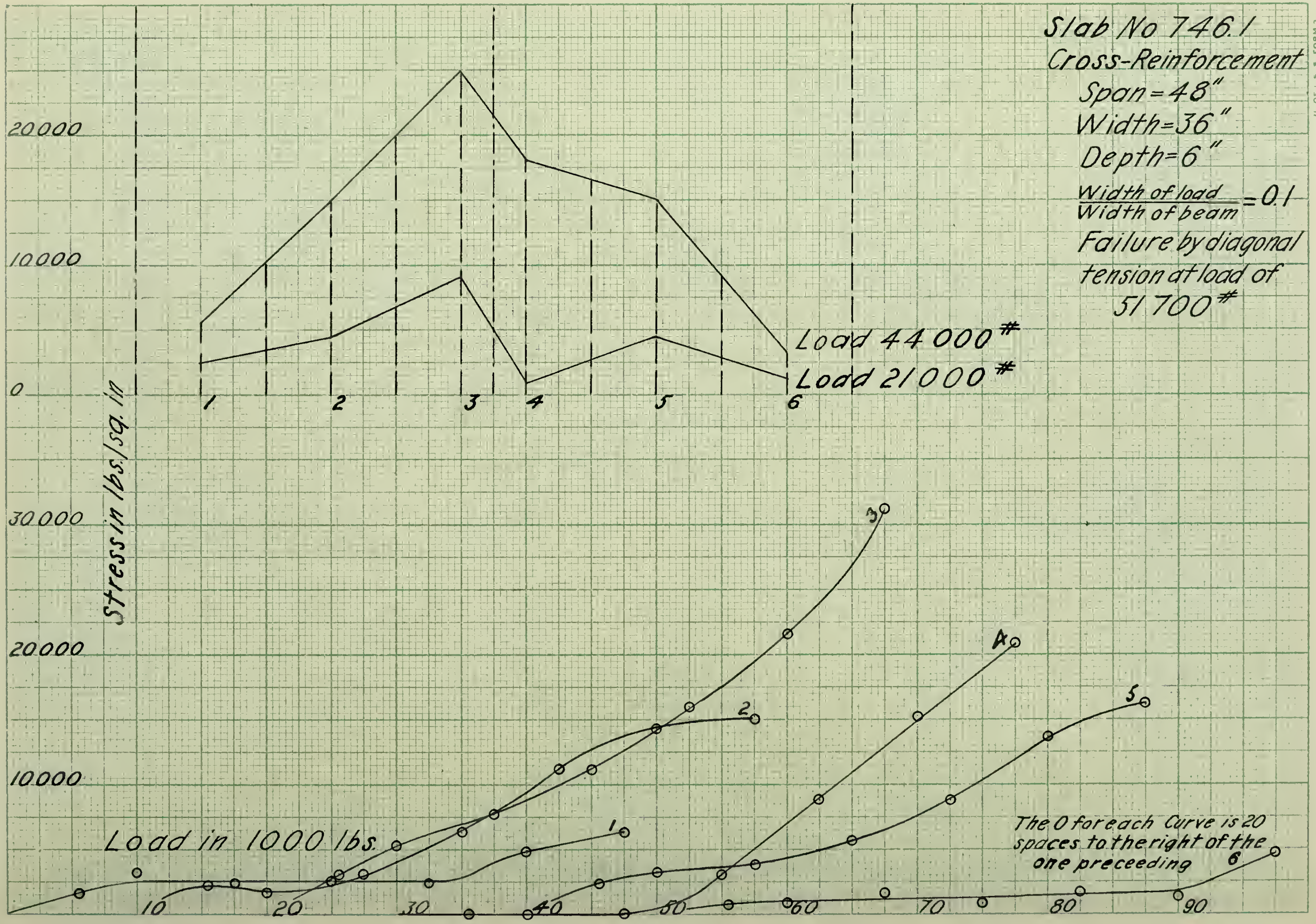
Slab No 745.2
Cross-Reinforcement
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure by diagonal tension at load of 57000#

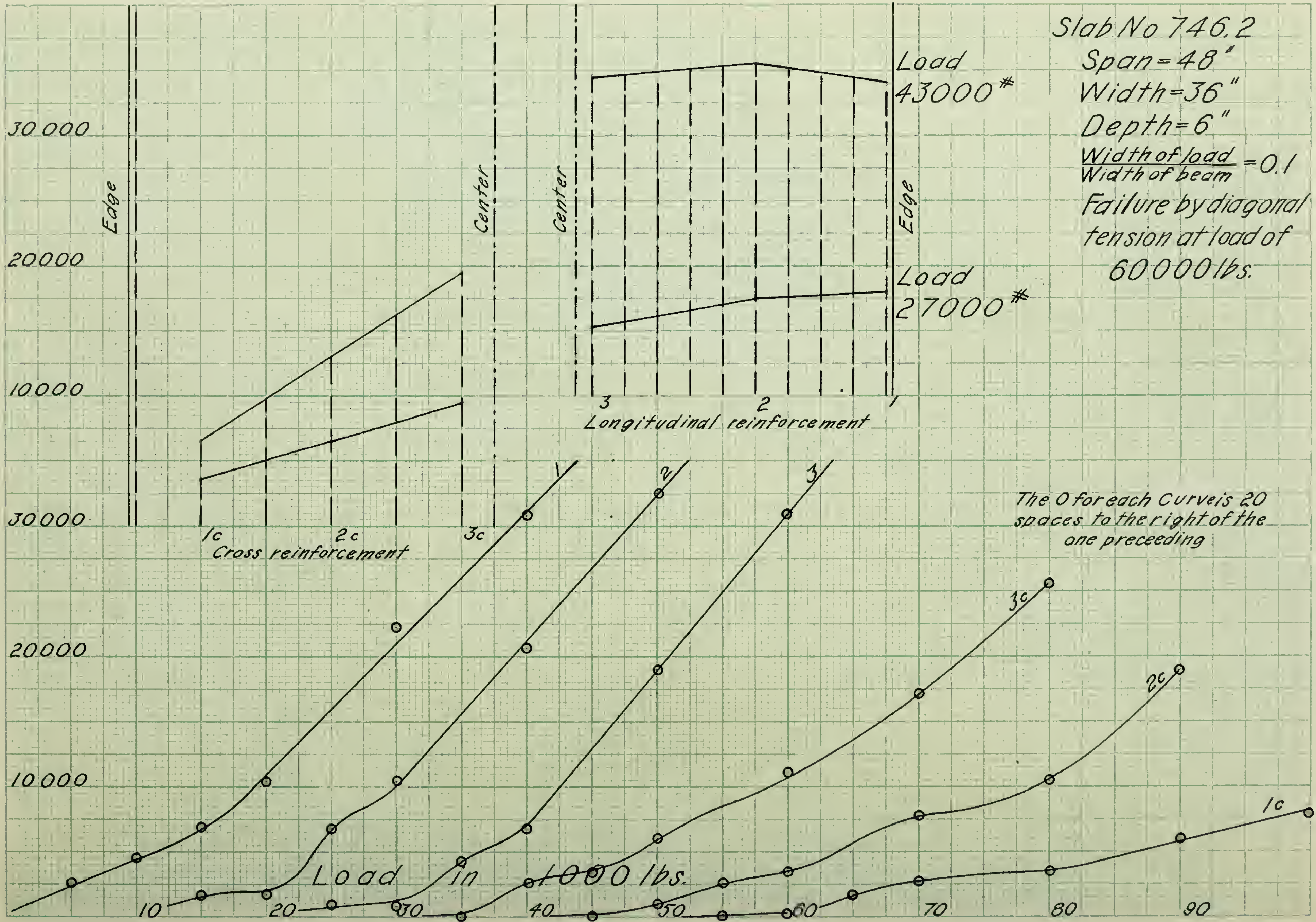
The 0 for each Curve is 20 spaces to the right of the one preceeding.



Slab No 746.1
Long. Reinforcement
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure by diagonal tension at load of 51700#

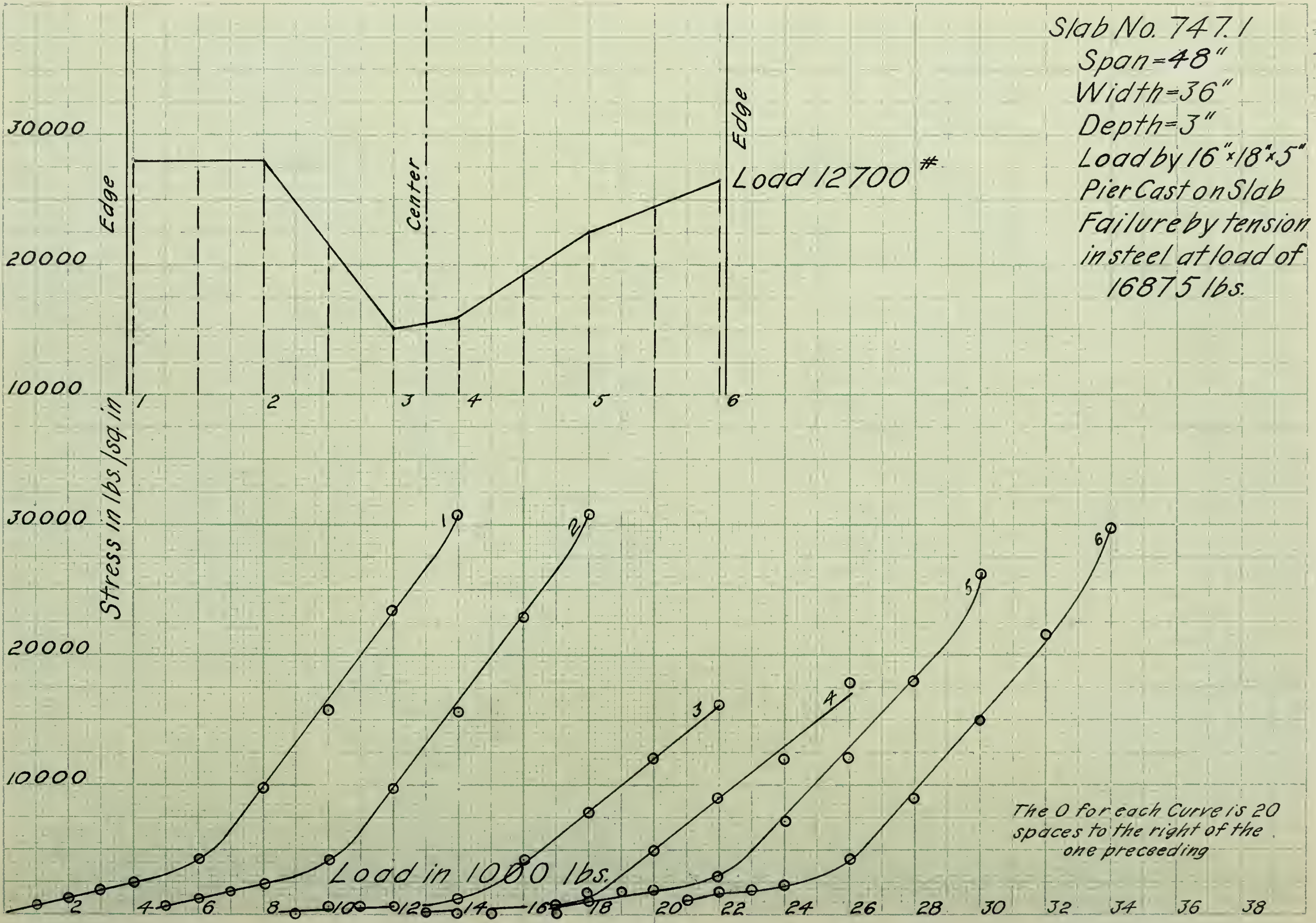
The 0 for each curve is 20 spaces to the right of the one preceeding

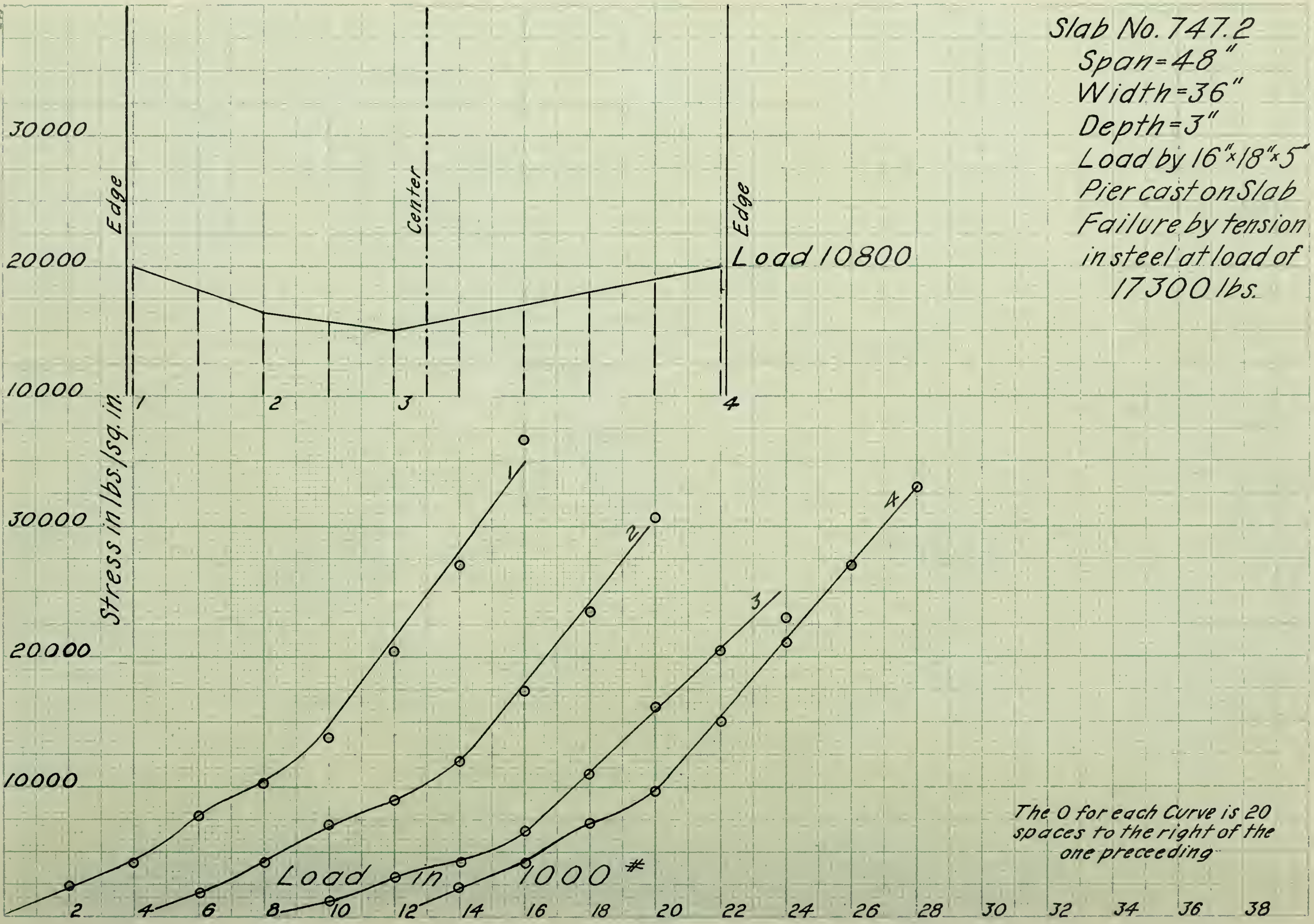

Slab No 746.1
Cross-Reinforcement
Span = 48"
Width = 36"
Depth = 6"
Width of load / Width of beam = 0.1
Failure by diagonal tension at load of 51 700#
Load 44 000#
Load 21 000#
Stress in lbs./sq. in
Load in 1000 lbs.
The 0 for each Curve is 20 spaces to the right of the one preceeding
0
10000
20000
30000
1
2
3
4
5
6
10
20
30
40
50
60
70
80
90

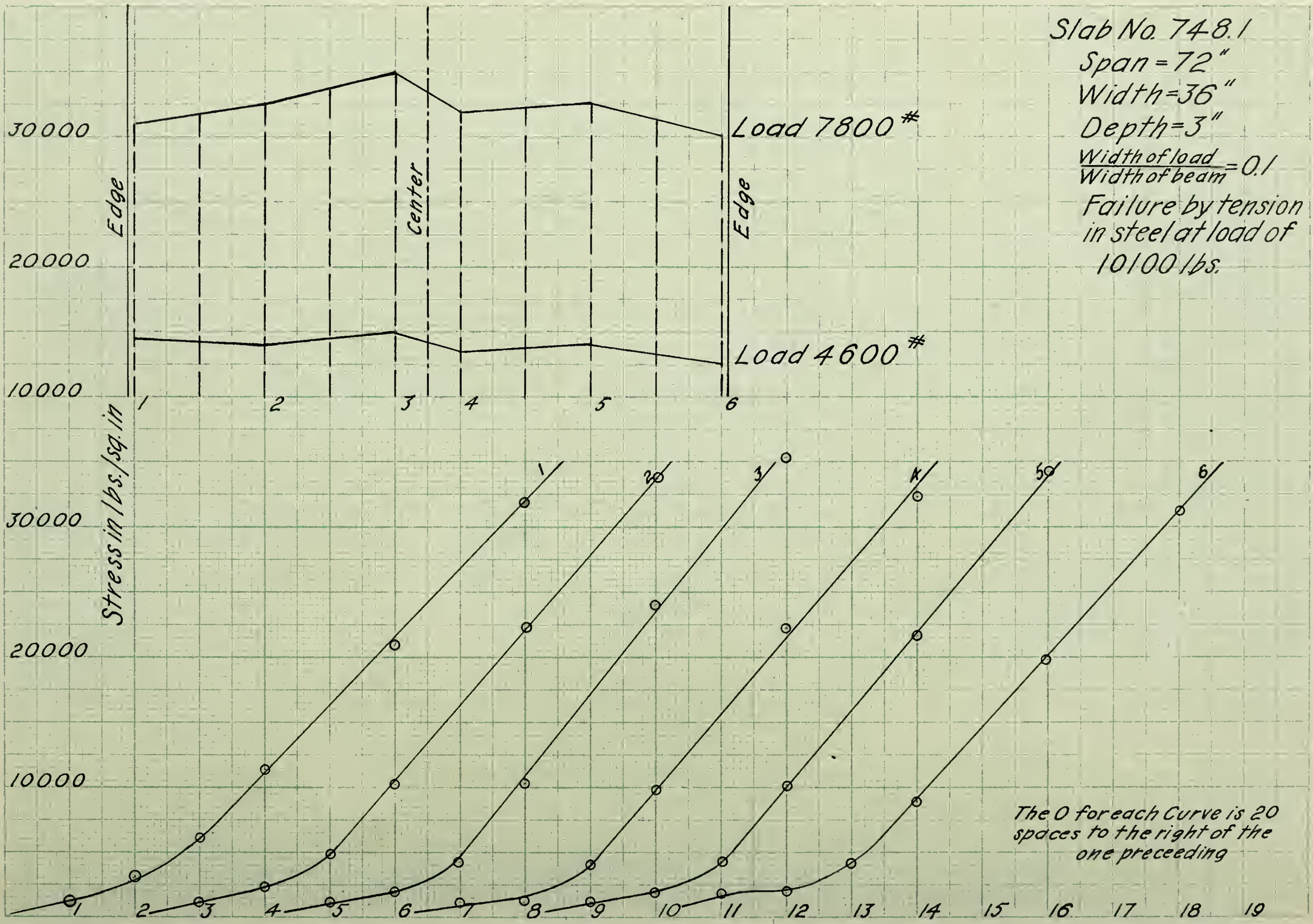


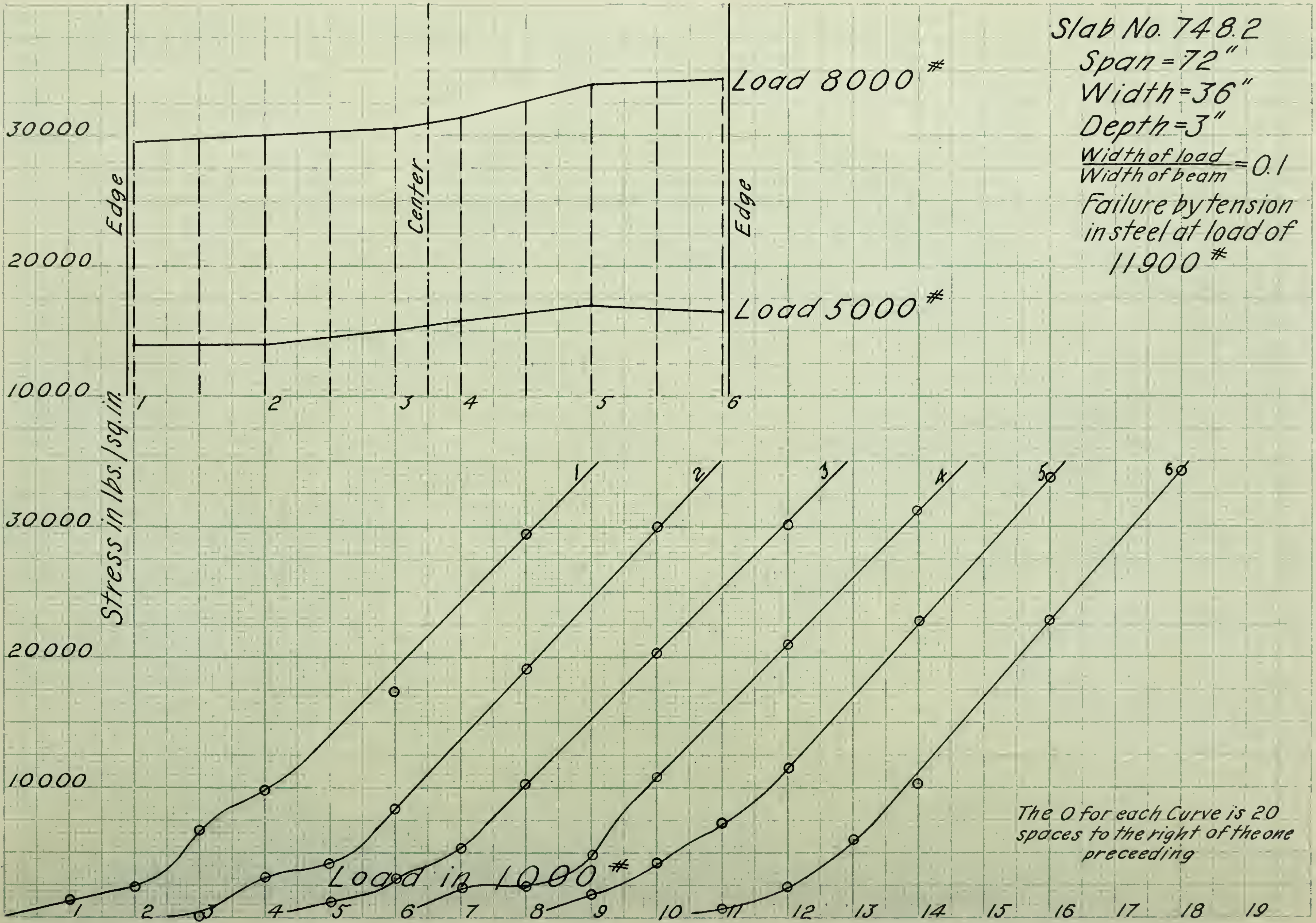
Slab No 746.2
Span = 48"
Width = 36"
Depth = 6"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure by diagonal tension at load of 60000 lbs.

The 0 for each Curve is 20 spaces to the right of the one preceeding


Slab No. 747.1
Span=48"
Width=36"
Depth=3"
Load by 16"×18"×5"
Pier Cast on Slab
Failure by tension
in steel at load of
16875 lbs.
Edge
Center
Edge
Load 12700 #
30000
20000
10000
1
2
3
4
5
6
Stress in lbs./sq. in
30000
20000
10000
1
2
3
4
5
6
Load in 1000 lbs.
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
The 0 for each Curve is 20
spaces to the right of the
one preceeding

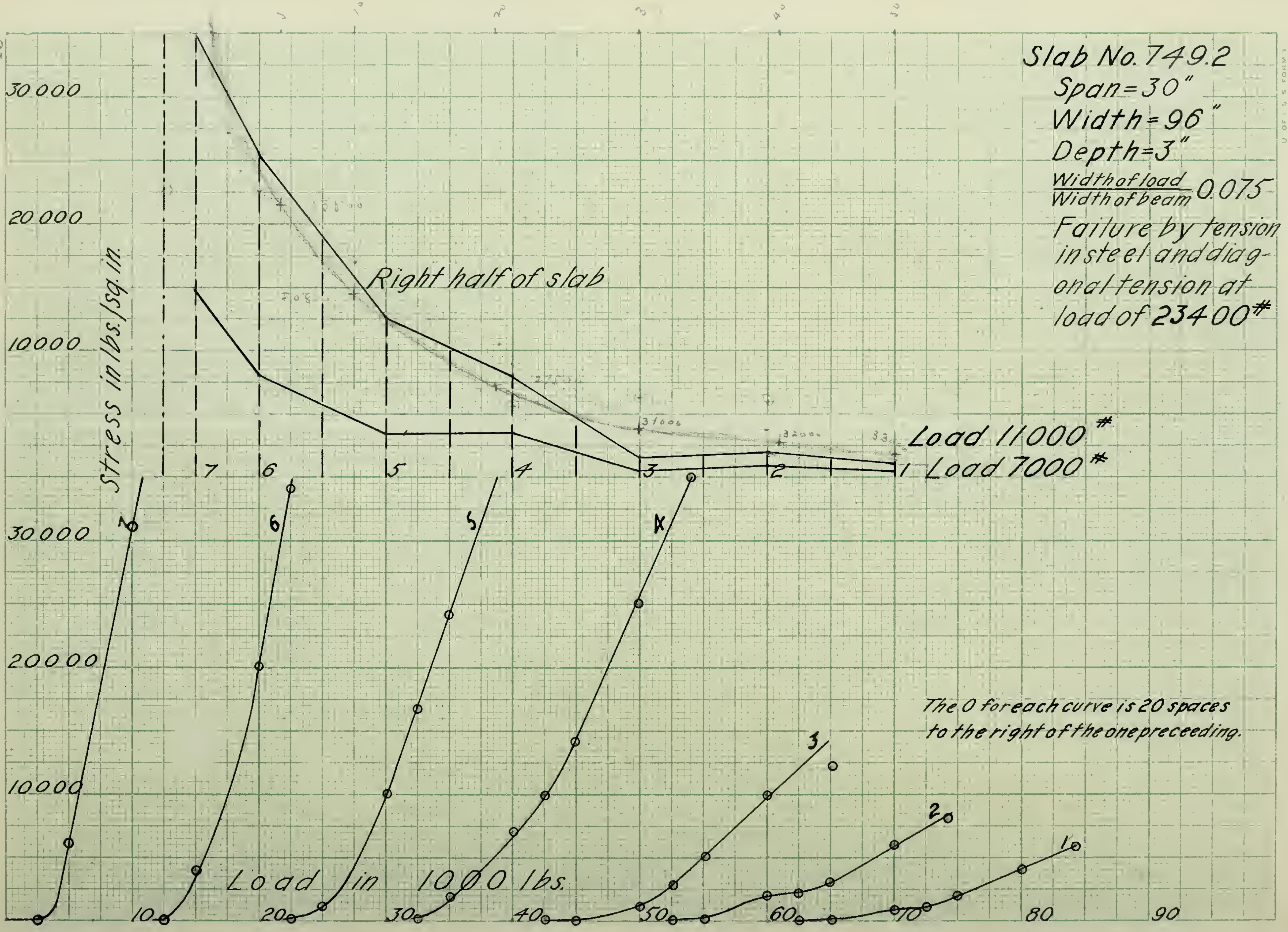

Slab No. 747.2
Span=48"
Width=36"
Depth=3"
Load by 16"×18"×5"
Pier cast on Slab
Failure by tension
in steel at load of
17300 lbs.
Edge
Center
Edge
Load 10800
30000
20000
10000
1
2
3
4
Stress in lbs./sq. in.
30000
20000
10000
1
2
3
4
Load in 1000 #
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
The 0 for each Curve is 20 spaces to the right of the one preceeding


Slab No. 748.1
Span = 72"
Width = 36"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure by tension in steel at load of 10100 lbs.
Edge
Center
Edge
Load 7800 #
Load 4600 #
30000
20000
10000
1
2
3
4
5
6
Stress in lbs./sq.in
30000
20000
10000
1
2
3
4
5
6
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
The 0 for each Curve is 20 spaces to the right of the one preceeding



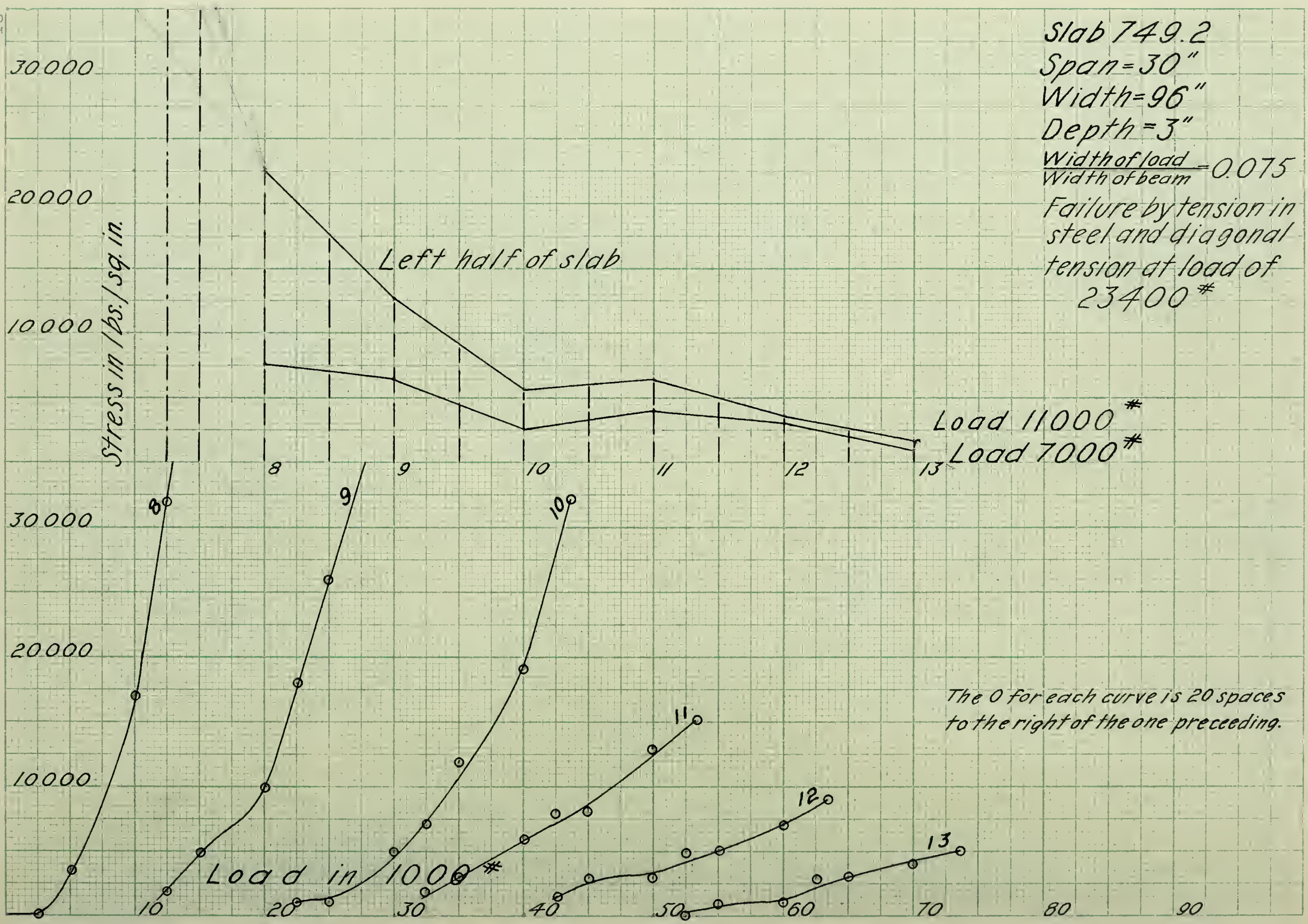
Slab No. 748.2
Span = 72"
Width = 36"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.1$
Failure by tension in steel at load of 11900 #

The 0 for each Curve is 20 spaces to the right of the one preceeding



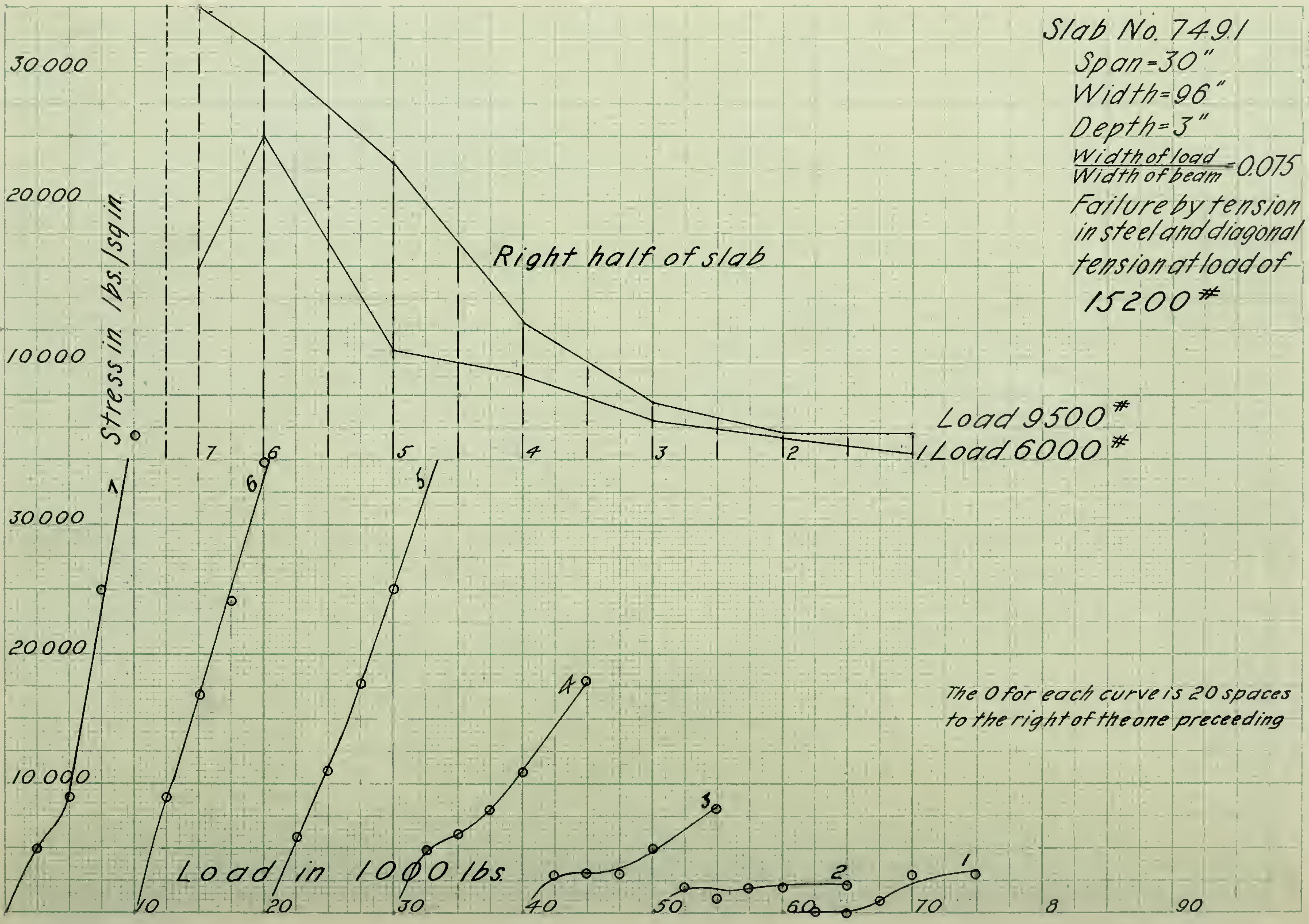
Slab No. 749.2
Span = 30"
Width = 96"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}}$ 0.075
Failure by tension in steel and diagonal tension at load of 23400#

The 0 for each curve is 20 spaces to the right of the one preceeding.



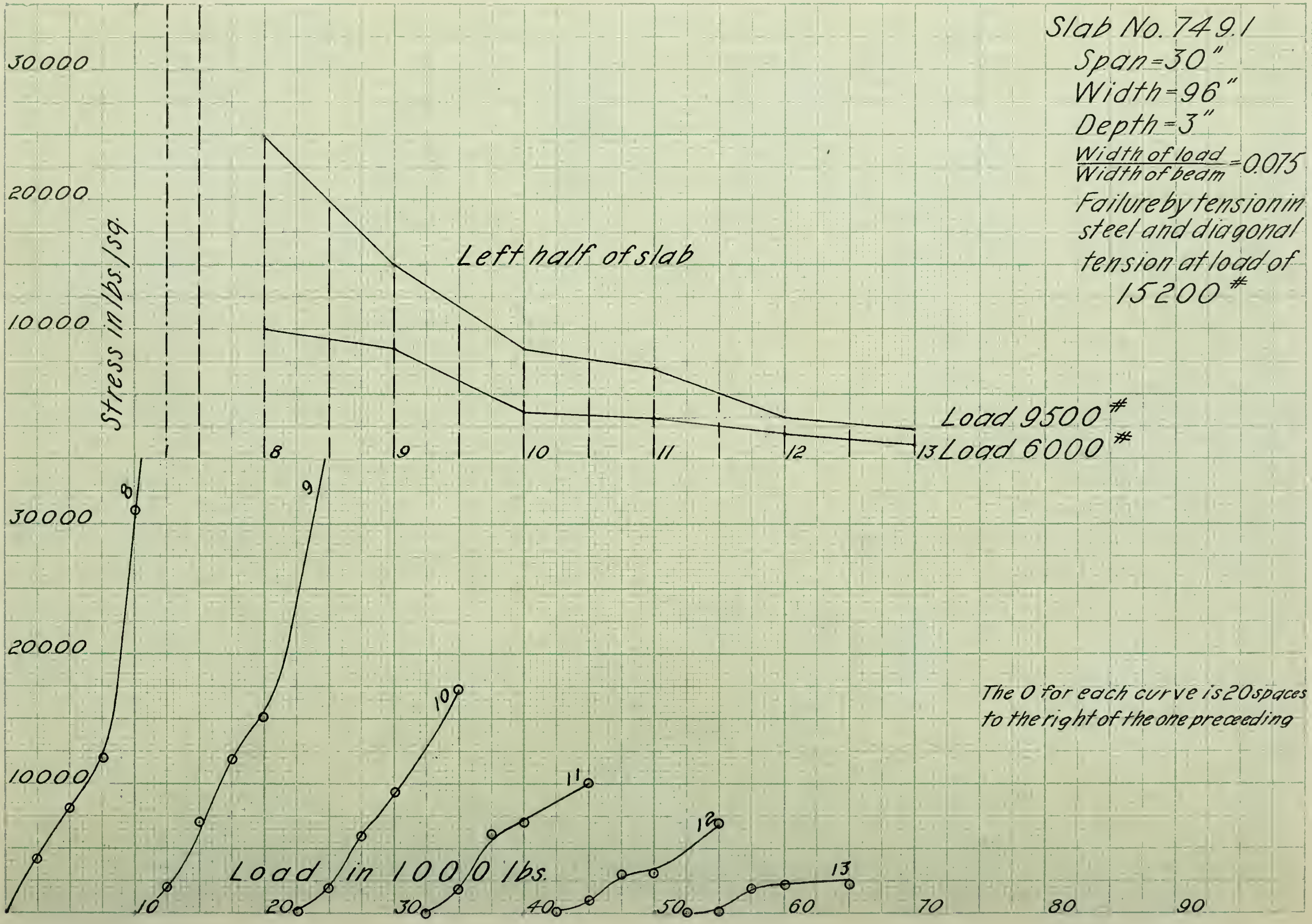
Slab 749.2
Span = 30"
Width = 96"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.075$
Failure by tension in steel and diagonal tension at load of 23400#

The 0 for each curve is 20 spaces to the right of the one preceeding.



Slab No. 749.1
Span = 30"
Width = 96"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.075$
Failure by tension in steel and diagonal tension at load of 15200#

The 0 for each curve is 20 spaces to the right of the one preceeding



Slab No. 749.1
Span = 30"
Width = 96"
Depth = 3"
$\frac{\text{Width of load}}{\text{Width of beam}} = 0.075$
Failure by tension in steel and diagonal tension at load of 15200#

The 0 for each curve is 20 spaces to the right of the one preceeding

IV CONCLUSIONS AND THEORETICAL STUDY

There are two points in the test of each beam, at which it is important to study stresses. The first is when working stresses are developed, and the second is just before failure. The results of the tests made on beams in which the span is greater than the width, seem to show that, at working stresses, the variation in stress due to concentration of the load can be neglected. In nearly all cases the stress in the steel at the edges of the beam was as great as that at the center. At least, the difference is very slight and is less than the variation due to unexplained causes. Where cross-reinforcement was used the stress in the cross-reinforcement was very small when the longitudinal reinforcement was stressed up to full working stress. Even at the highest stresses in the longitudinal steel, the variation due to concentration of the load was very slight, but to avoid failure by diagonal tension or as a slab, other reinforcing was necessary. The data obtained does not seem to offer a means of determining the exact amount of cross-reinforcement necessary to prevent slab failure, but it does show that a very little is sufficient. Where only 0.22 per cent was used the maximum stress was only 20 000 lbs. per sq. in. while the stress in the longitudinal steel was 35 000 lbs. per sq. in.

We may say then in conclusion, for slabs in which the span is greater than the width, that for calculating the longitudinal reinforcement, the load may be considered as distributed over the entire beam and as far as these tests indicate, failure as a slab

can be prevented by less than 0.22 per cent of cross-reinforcing.

Where the width is much greater than the span, not nearly all the strength of the longitudinal steel is developed before failure, as is shown by the results of the tests of beams numbered 749. There are two ways of studying beams of this class; first, by determining what amount of cross-reinforcement is necessary to develop the entire strength of the longitudinal reinforcement; or second, if cross-reinforcement is not used, to determine what proportion of the strength of the longitudinal steel will be developed, when a given load of given concentration is applied. For the beams tested of this class, an attempt will be made to determine what proportion of the steel can be considered effective in carrying load.

Consider beam number 749.1 when rod number 7, directly under the load, has a stress of 15 000 lbs. per sq. inch. Adding up the stresses per square inch in all rods as taken off the diagram on the upper part of pages 47 and 48, we have for the total stress in the steel,

$$f_s = 164\ 500 \text{ lbs. per sq. in.}$$

If each bar took a stress of 15 000 lbs. per sq. in. the number of bars required would be

$$N = 164\ 500 \div 15\ 000 = 11$$

The proportion of the beam effective for carrying load then is $11 \div 24$ or 0.46.

The proportion, when worked out for the same beam number 749.1 at a stress of 35 000 lbs. per sq. in. in its center rods is 0.37.

These proportions, when worked out for beam number 749.2, are found to be 0.29 for a stress of 15 000 lbs. per sq. in., and 0.294 for a stress of 35 000 lbs. per sq. in. The actual width of the beam that can be considered effective in carrying load is

$$W = 0.29 \times 96$$
$$= 28 \text{ inches.}$$

On account of having to hurry the test of this last beam, the usual stiffness of the concrete was not developed and probably the result is a little low. Furthermore, these results cannot be interpreted too closely on account of a certain amount of error in observation, and variation in concrete. It seems safe, however, to consider 30 inches, or a width equal to the span as effective in carrying load. This result agrees with the results obtained from the tests of the beams narrower than the span which did not show material variation in stress laterally. In lieu of a more complete analysis founded upon more extended data the following empirical rule is offered, that a width of beam equal to the span can be considered effective in carrying load irrespective of the concentration, which seems to be verified by these tests.